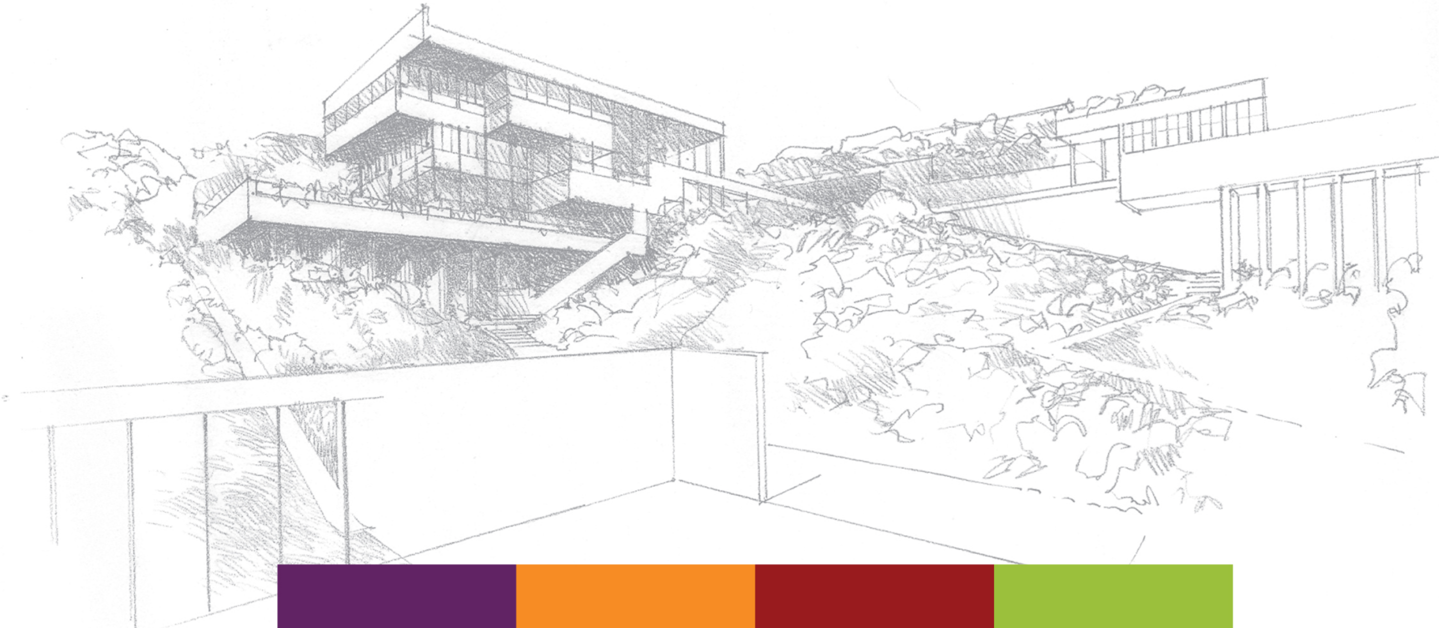
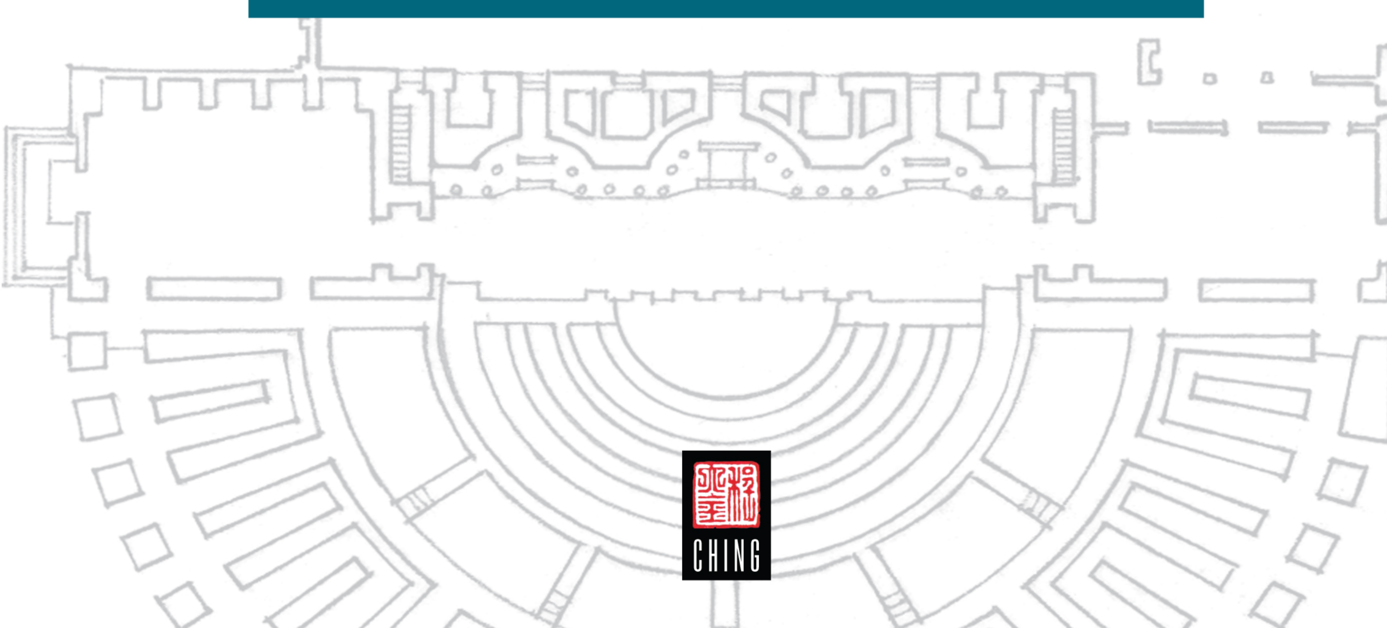


FRANCIS D.K. CHING

JAMES F. ECKLER

INTRODUCTION TO ARCHITECTURE



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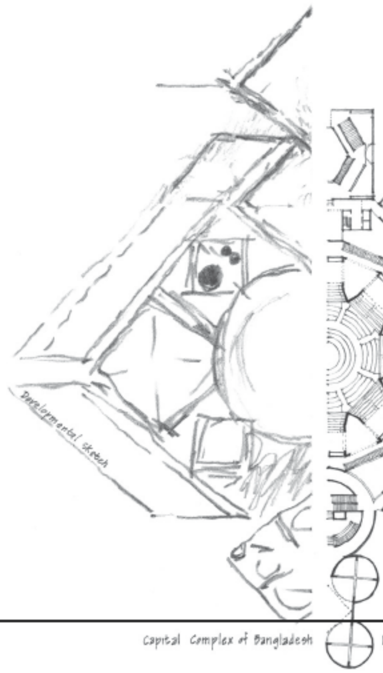
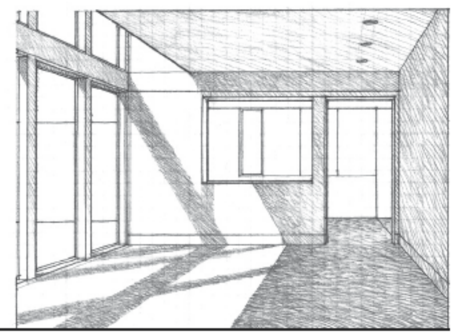
Introduction to Architecture





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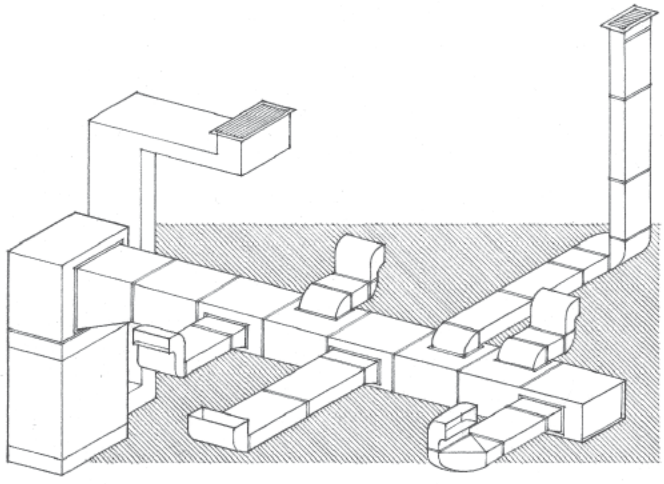
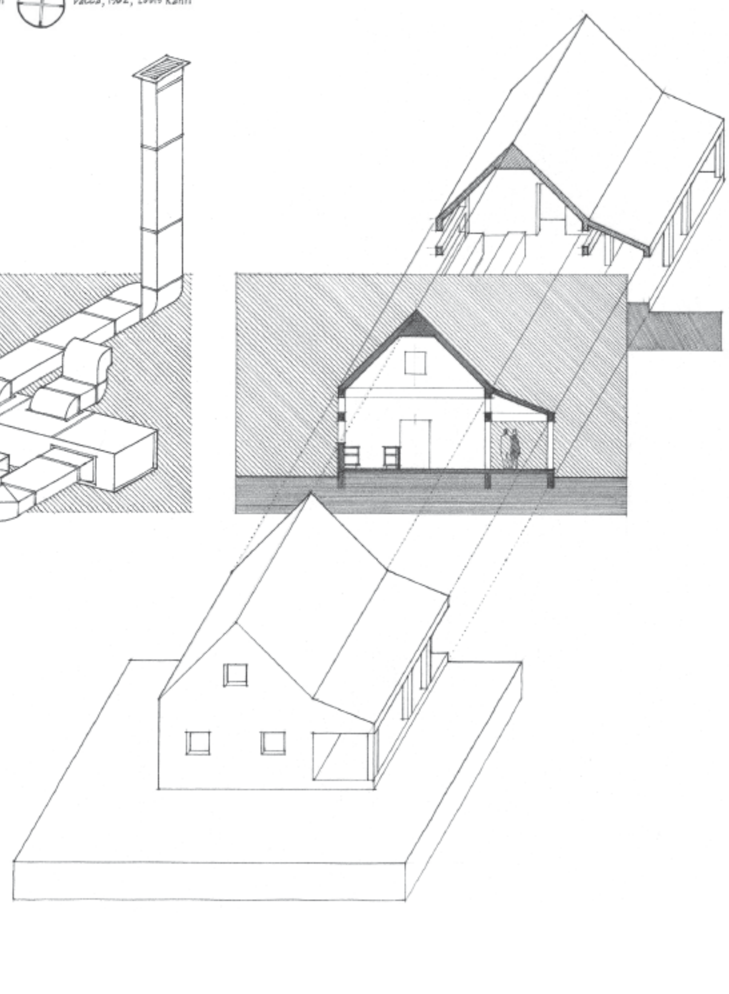
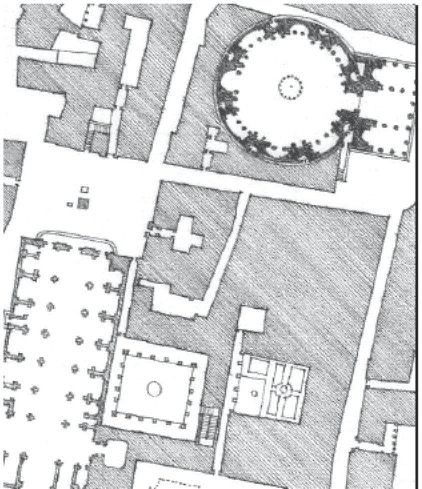
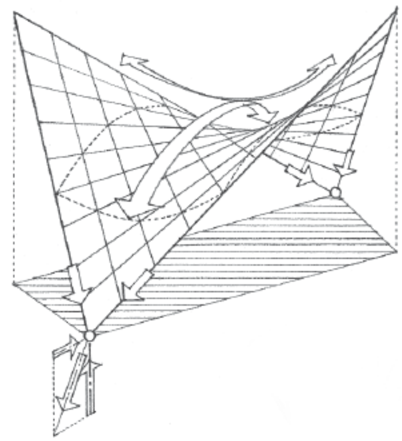
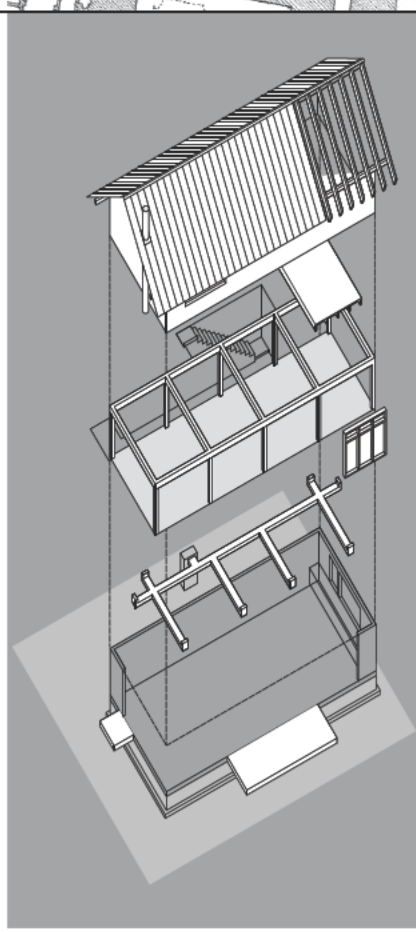


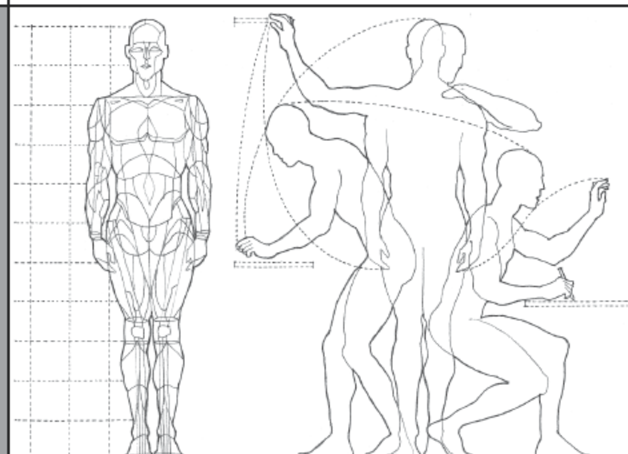


Introduction to Architecture









Francis D.K. Ching
James F. Eckler

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Contents

Preface

Architecture is a multifaceted subject. It was born from the necessity for shelter, forged by the science of materials and energy, and made into an art form by our creative instincts and search for meaning. It reflects culture and society as it responds to real and imagined human needs.

Architecture is an integral part of our lives. Good design, often unnoticed, quietly facilitates the activities of everyday life. It is the architect's challenge to create spaces that are perfectly attuned to the activities that take place within them. This text seeks to illuminate some of the tools and techniques at the architect's disposal in facing this challenge. Perhaps, after studying the pages of this book, some of the qualities of buildings that were previously unnoticed will become apparent.

To compile an introductory text that covers the many facets of architecture in a concise and coherent manner, we have compiled material from the following publications, all from Wiley. Additionally, all-new information has been generated for this text that addresses the relationship between architecture and its urban context.

- ***A Global History of Architecture*** by Francis D. K. Ching, Mark Jarzombeck, and Vikramaditya Prakash.
  This text illustrates the evolution of architecture in the context of world events that motivated it to change. Brief segments of this text are included to introduce the reader to a small part of architecture's rich past, diversity, and cultural significance.

- ***Architecture: Form, Space and Order*** by Francis D. K. Ching.
  This text presents characteristics fundamental to all architecture. Content from this text is included for the reader to be made aware of some of the design principles and strategies employed by architects.

- ***Building Codes Illustrated*** by Francis D. K. Ching and Steven R. Winkel.
  Building codes are important legal constraints for architectural design. This text details the legal requirments of architecture. This content is included to provide the reader with a better understanding of some of architecture's legal and social responsibilities.

- ***Building Construction Illustrated*** by Francis D. K. Ching.
  This text details the many materials and methods of construction commonly used in buildings today. This content is included for the reader to understand the impact of construction methods on design descisions made by architects.

- ***Design Drawing*** by Francis D. K. Ching and Steven P. Juroszek.
  This text illustrates various drawing techniques used by architects to represent and communicate their ideas. This content is intended to present the architect's required range of skill as well as provide the reader with an understanding of the complexity of the design process from idea through final construction.

- ***Interior Design Illustrated*** by Francis D. K. Ching and Corky Binggeli.
  This text explains the discipline and profession of Interior Design. Content from this text is included to provide the reader with an understanding of the professional, disciplinary, and philosophical relationships between architecture and interior design.

- ***A Visual Dictionary of Architecture*** by Francis D. K. Ching.
  This text assembles a comprehensive list of architectural components, elements, and systems. It provides detailed definitions of their use or importance as well as graphic illustrations. This content is included to provide the reader with a better understanding of the components that make up a building and to expand his or her architectural vocabulary.

- ***Language of Space and Form: Generative Terms for Architecture*** by James Eckler.
  This text assembles a comprehensive list of architectural design principles and concepts. It outlines ways in which these principles can be used to generate ideas in the early stages of the design process. This content is used to introduce and link the diverse topics presented in *Introduction to Architecture*.

We hope that this compilation will both inspire and instruct as it introduces students to the art and discipline of architecture. If at any time more information about a certain topic is needed, we recommend that the reader consult any of the above publications.

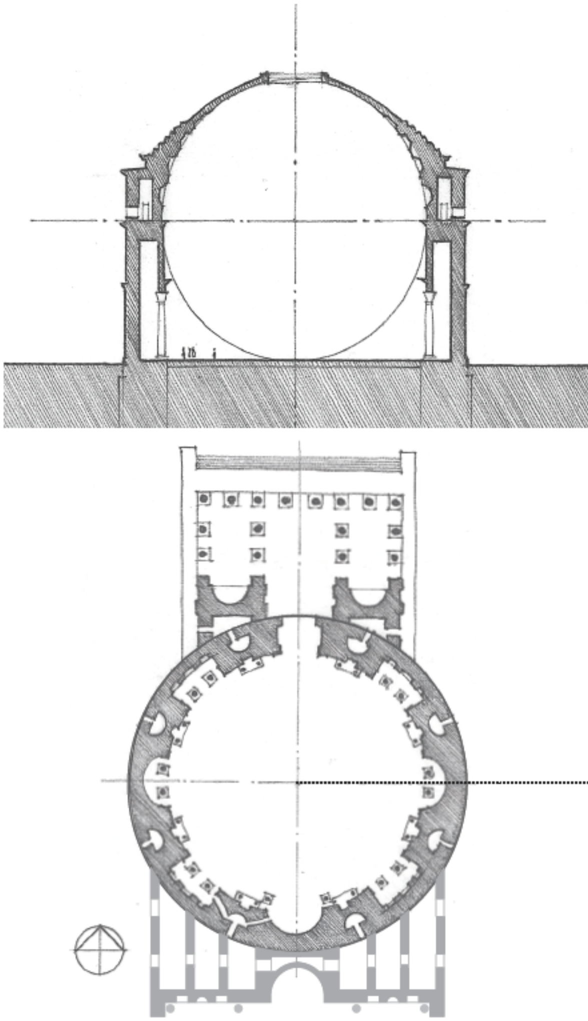
Metric Equivalents

The International System of Units is an internationally accepted system of coherent physical units, using the meter, kilogram, second, ampere, kelvin, and candela as the base units of length, mass, time, electric current, temperature, and luminous intensity. To acquaint the reader with the International System of Units, metric equivalents are provided throughout this book according to the following conventions:

- All whole numbers in parentheses indicate millimeters unless otherwise noted.
- Dimensions 3 inches and greater are rounded to the nearest multiple of 5 millimeters.
- Nominal dimensions are directly converted; for example, a nominal 2 x 4 is converted to 51 x 100 even though its actual 1 $^1/_2$" x 3 $^1/_2$" dimensions would be converted to 38 x 90.
- Note that 3487 mm = 3.847 m.
- In all other cases, the metric unit of measurement is specified.

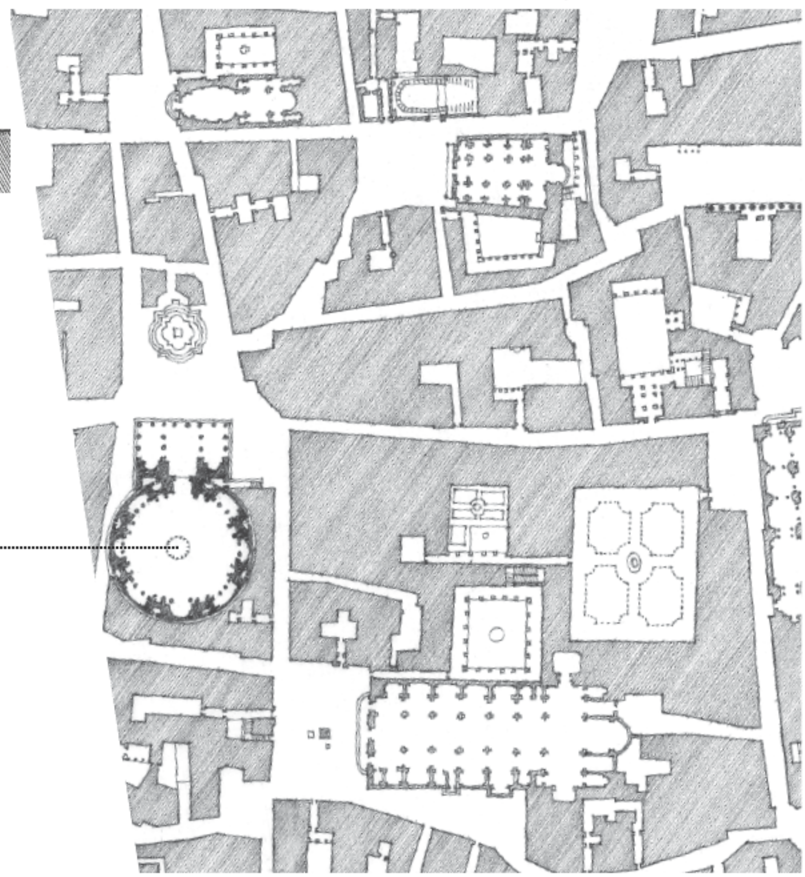
1 Introduction:

Object, Space, Building, City



Pantheon, Rome, 126 CE

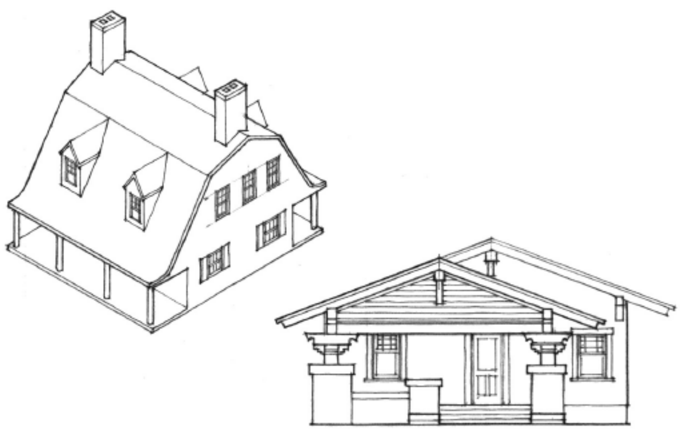
Portion of Giambattista Nolli's map of Rome, 1736–1748



The mother art is architecture.
Without an architecture of our own we have no soul of our own civilization.
— Frank Lloyd Wright

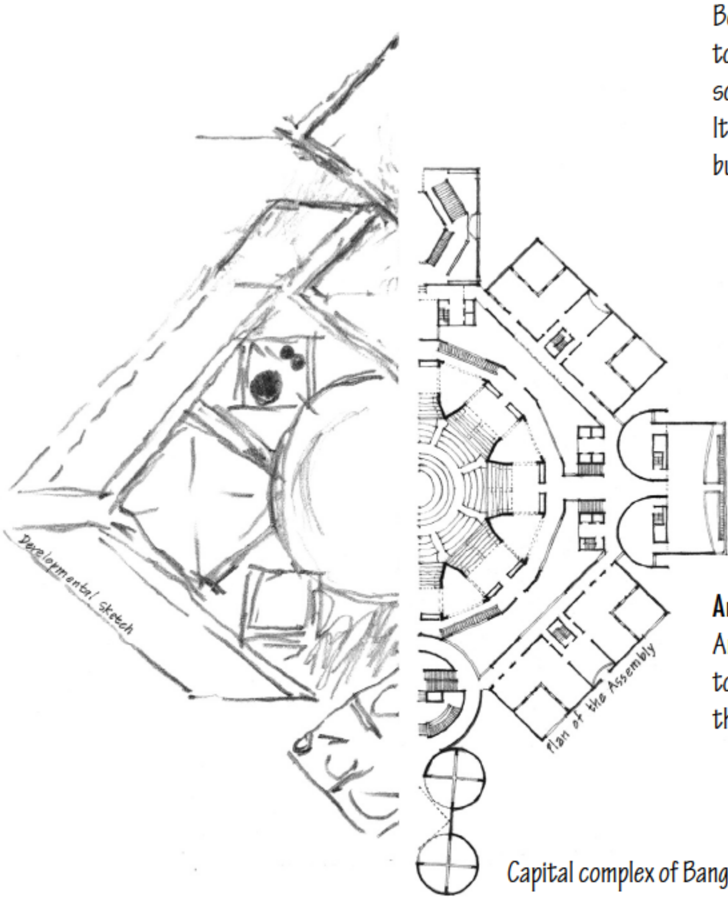
What Is Architecture?

Architecture is a very complex discipline. Most people live their lives in constant contact with architecture. It provides a place to dwell, work, and play. With so much responsibility for determining our experiences, and with such a variety of uses, architecture has too many forms to be precisely categorized. One house is used essentially the same way as any other, but how many different sizes, shapes, or configurations are possible for a house? There is no single correct formula for determining the perfect layout of a house, or any other type of building. At the same time as architecture is indefinite, it also has a responsibility to facilitate specific functions.



Houses may come in various forms and densities

Because of the diverse forms architecture can take and the need for it to function in specific ways, it should be considered both an art and a science. It is an artistic discipline that seeks to invent through design. It is also a technical profession that relies on specific techniques of building construction.



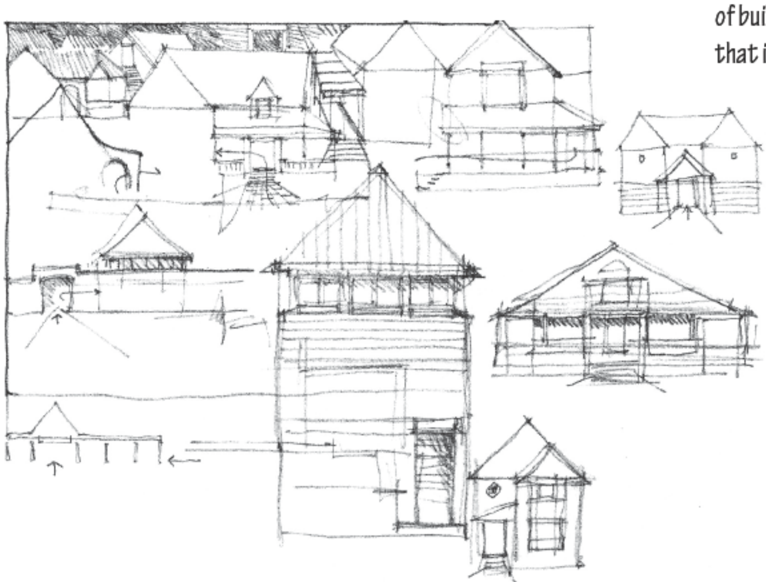
Artistic Discipline and Technical Profession

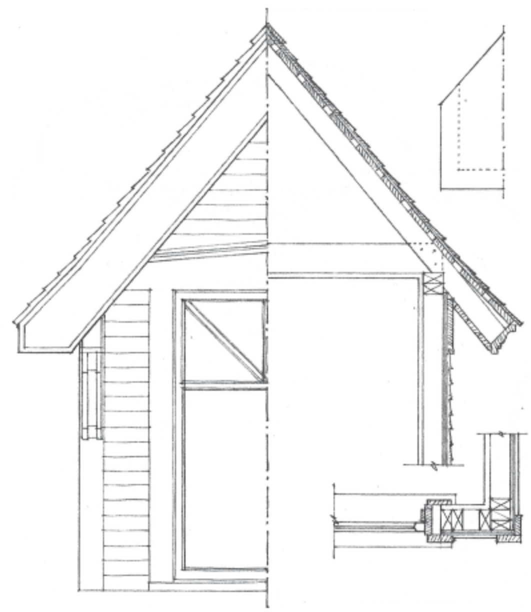
Architects can use almost any techniques for drawing or making models to develop their ideas. However, they must document and communicate those ideas using a universally understood graphic language.

Capital complex of Bangladesh, Dacca, 1962, Louis Kahn

Creative Process and Construction Method

Architects go through many versions of an idea to perfect it. They experiment with different materials and modes of representing their ideas in order to develop them. However, all of the ideas that are layered into the design of a building must be realized using conventional methods of building construction. As the idea develops, it must remain something that is possible to build.



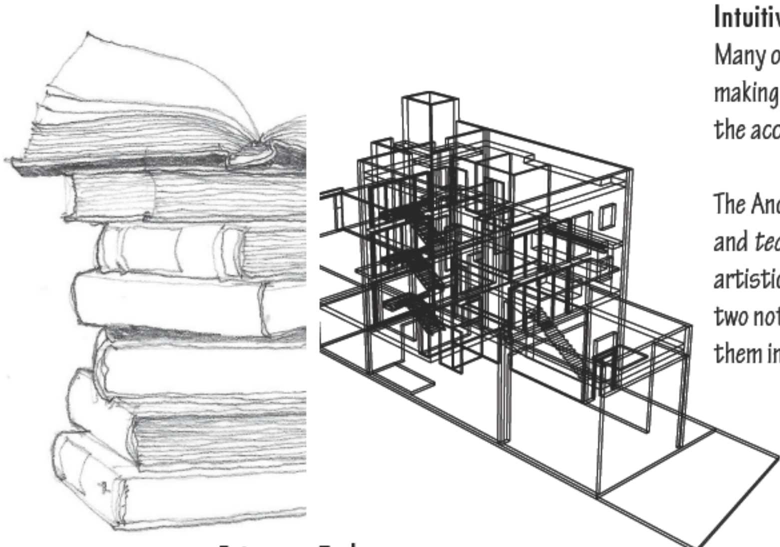


The development of an idea through a series of sketches leading to a construction drawing of the finished idea

Intuitive and Academic

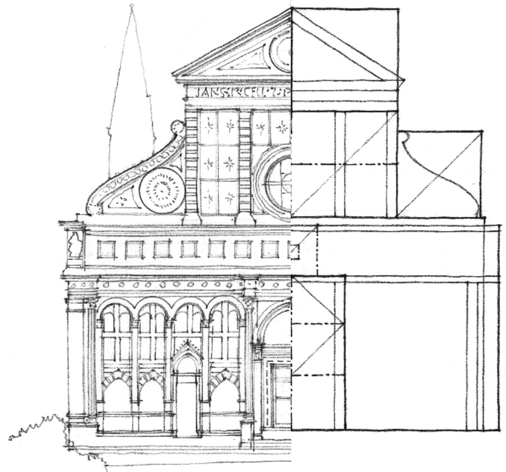
Many of the architect's ideas occur spontaneously, or through the act of making a drawing or model. Many also come from study and research and the accumulation of knowledge over time.

The Ancient Greeks called these two sides of architecture *episteme* and *techne*. Episteme is the pursuit of knowledge. Techne is a craft or artistic pursuit. To understand architecture one must realize that these two notions are intertwined and are often overlapped in ways that make them interchangeable.



Episteme Techne

The two parts of architecture are realized through what architects refer to as "the design process." The design process is the series of steps that are taken to develop a building from initial idea through the final proposal. While designing, architects must continually move back and forth between the creative act of architecture and the technical understanding of how a building is built.



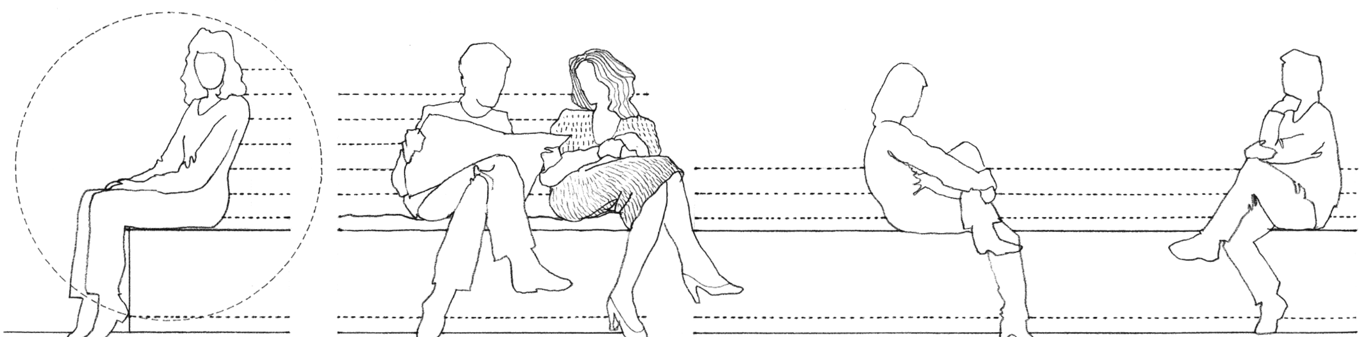
S. Maria Novella, Florence, Italy
Leon Battista Alberti designed the Renaissance facade (1456–1470) to complete a Gothic church (1278–1350).

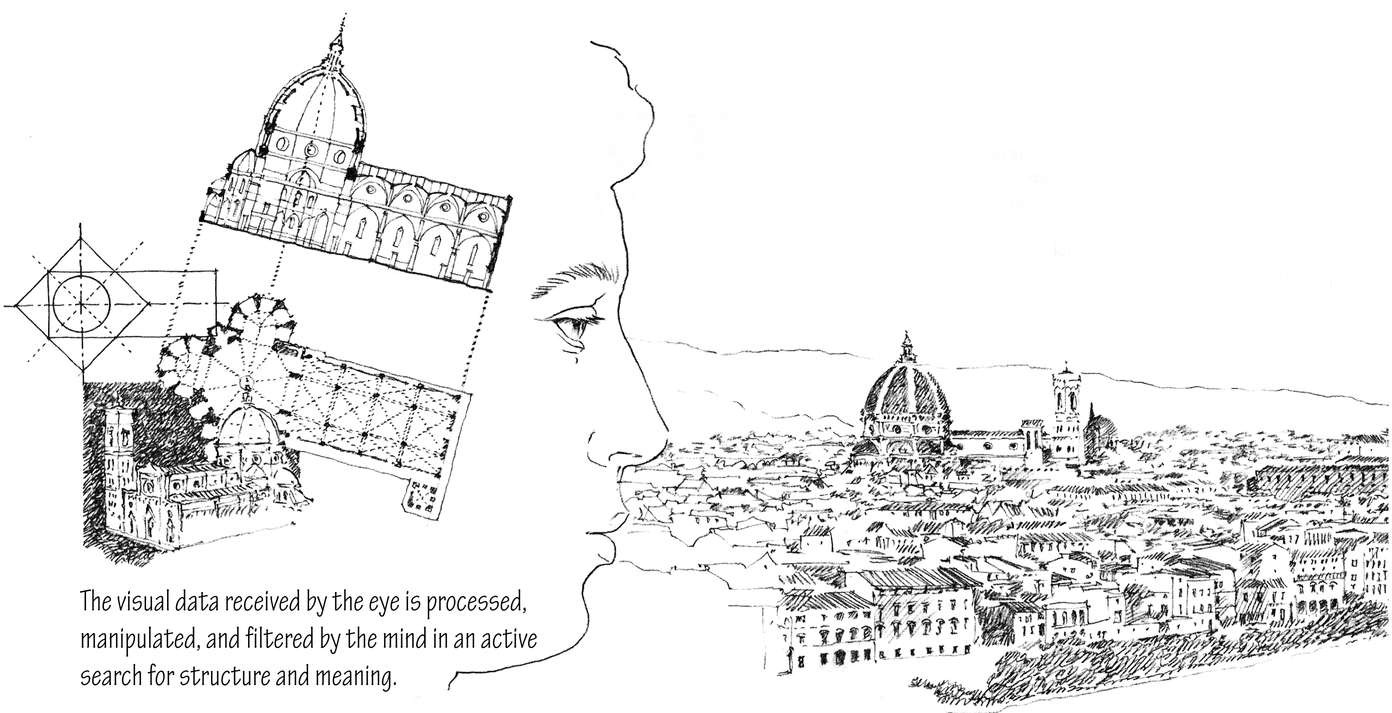
Episteme

Architectural episteme lies in the inquiry that is intrinsic to the design process. In the design process many questions are asked. Those questions define the problem that a design is meant to solve. To answer these questions, the architect must rely on a body of knowledge to inform design decisions. In designing a building, the architect tries many different versions of an idea in order to test and refine it. Through this process, new ideas can be generated as discoveries are made—many of which are unexpected but can still be traced to a fundamental knowledge of architecture and its contributing disciplines.

The following are aspects of architecture that refer to a pursuit of knowledge.

- History
- Theory
- Human behavior
- Human perception





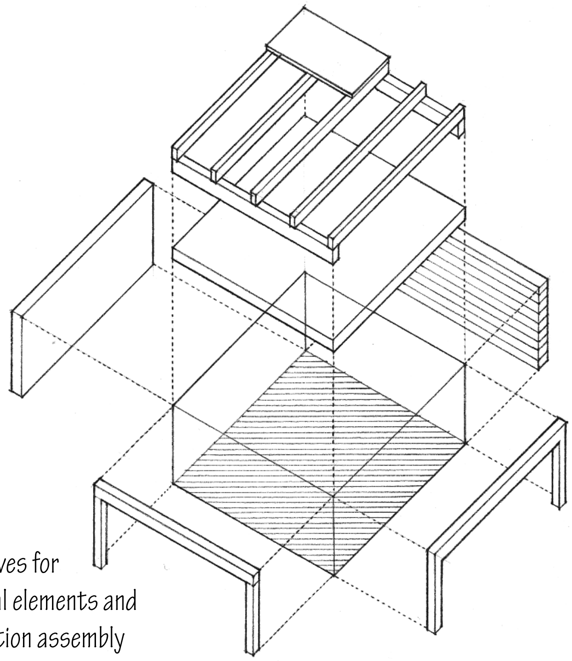
The visual data received by the eye is processed, manipulated, and filtered by the mind in an active search for structure and meaning.

Techne

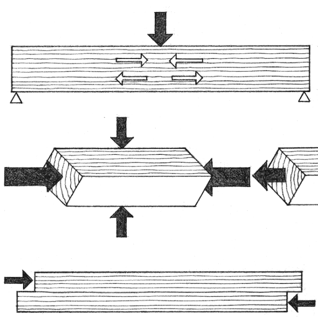
Architectural techne lies in the craft of building and the application of technique in design. It is the art and craft of building. In the design process, discoveries are made through the act of making. The architect must know how to draw and represent an idea before he or she can see if it adequately solves the design problem. Different techniques for representing an idea can allow the architect to investigate it in a variety of ways and better understand how it works. Additionally, an understanding of construction techniques and technologies can yield a more feasible building at the end of this process.

The following are elements of architecture that refer craft or technique:

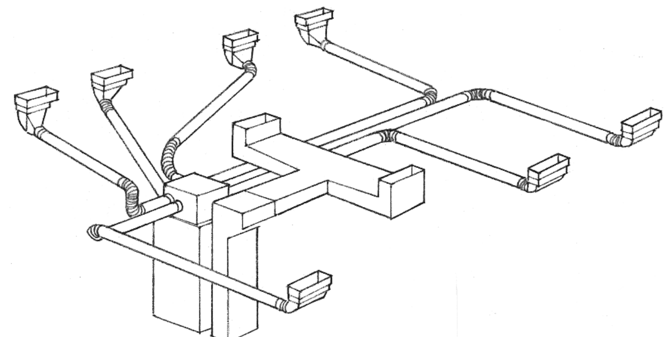
- Construction methods
- Material attributes
- Building technology
- Representation and communication (through drawing or model)



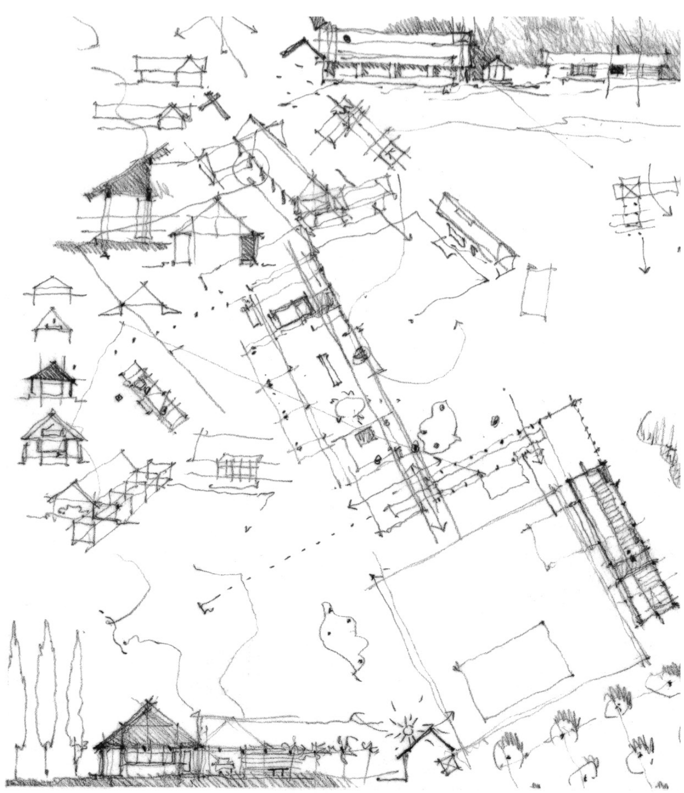
Alternatives for structural elements and construction assembly



Grain direction is the major determining factor in the way it is used as a structural material.

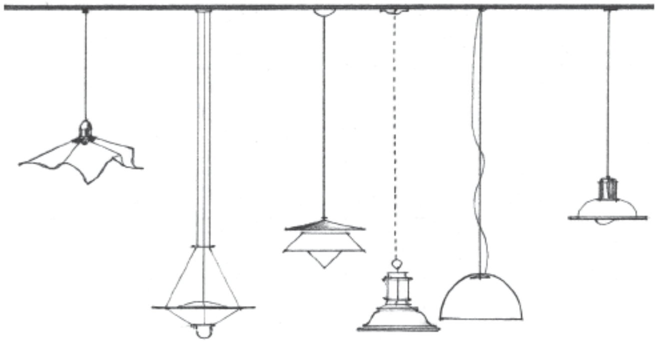


Mechanical and electrical systems maintain necessary conditions of comfort, health, and safety for the occupants of a building.



Design Thinking

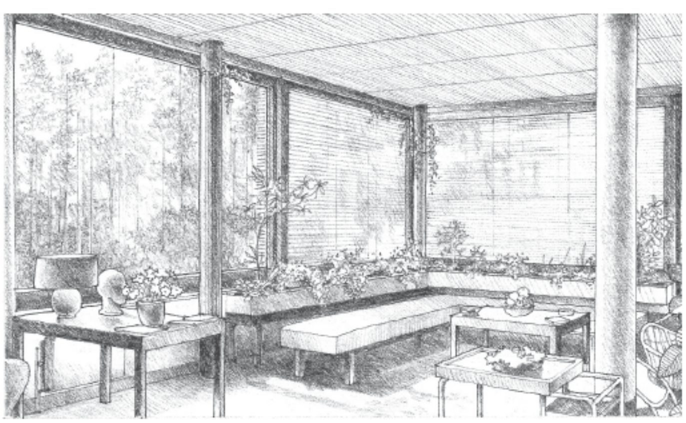
Taken together, these qualities of architecture inform design thinking. They define the way an architect generates ideas for a building. They also provide the architect with the tools necessary for design in a more general sense of the word. The priority of architecture is habitation—a design of the way people will occupy and use an environment. This has a broad range of applications that demand that the architect design at a variety of scales—from the size of a doorknob to that of a city block.



Examples of suspended light fixtures

Print by Joan Miró

Chairs by Arne Jacobsen and Alvar Aalto



Living room, Villa Mairea, Noormarkku, Finland, 1938–1939, Alvar Aalto

The Scale of Design

The domain of architecture is not just buildings. The architectural design process is one that translates to a variety of scales and is applicable to the design of objects, spaces, and even cities. Of course, the primary role of the architect lies in designing buildings, but there are many aspects of a building that require the architect to design at both smaller and larger scales. Architecture is a discipline of design, and the following are other facets of architectural design.

Designing Objects

Building design ranges from considerations of site down to the detail. Building details are designed toward specific functions of space. They also require the skills necessary to design as a very small scale. In addition to the detail, the architect can apply these skills toward the design of objects. Those objects might be directly related to building design, such as an ornament or a door handle. They might also be isolated projects that tap the skill sets possessed by an architect.

- Furniture design requires the architect's design sensibility and knowledge of ergonomics.
- Lighting design requires an architect's understanding of the behavior of light and desire to create a particular experience with light.
- Sculpture and painting are often pursued by architects because of the similarity of compositional principles and crafting technique.

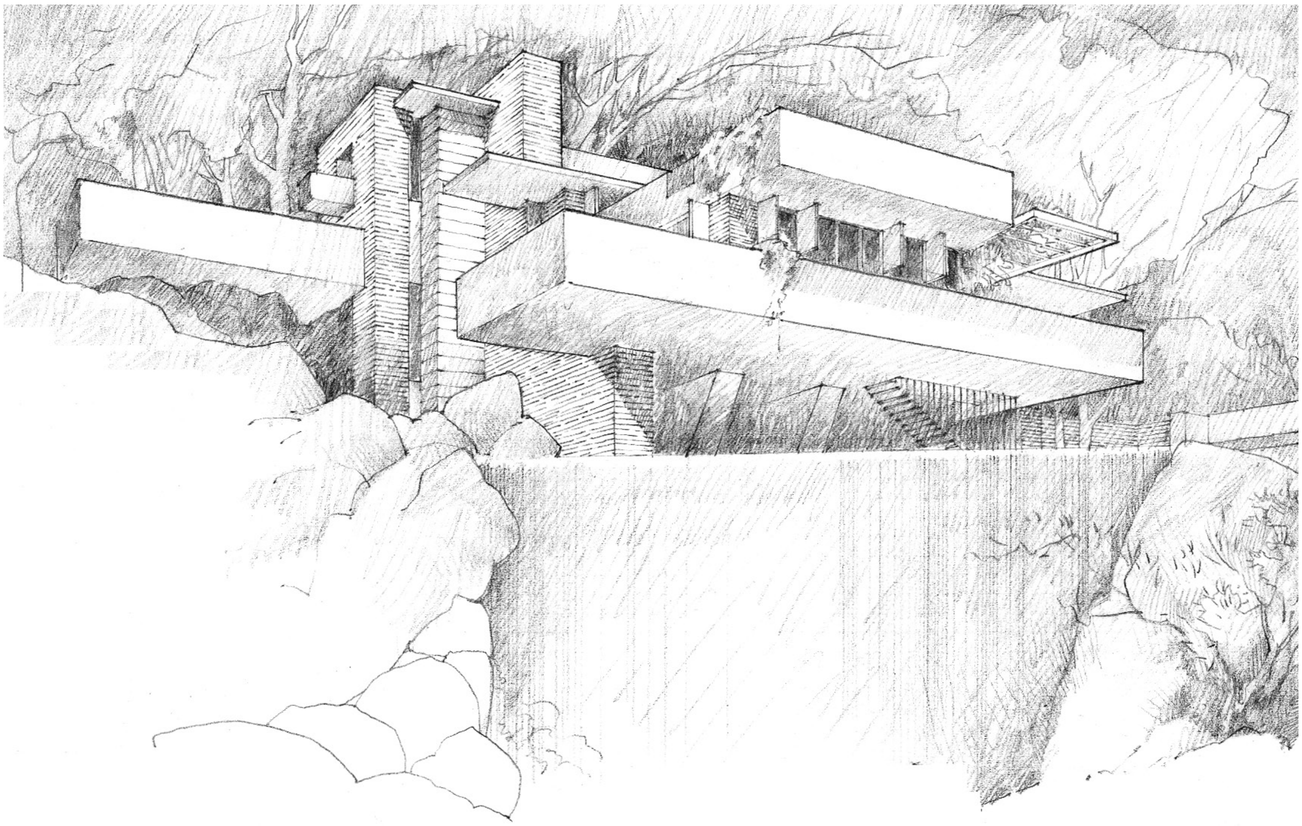
Designing Spaces

One of the fundamental qualities of architecture is space. The architect is not just required to design a building but to configure the spaces within that building so that they can be used for a specific function. Designing spaces requires the architect's understanding of proportion, organization, light, and material.

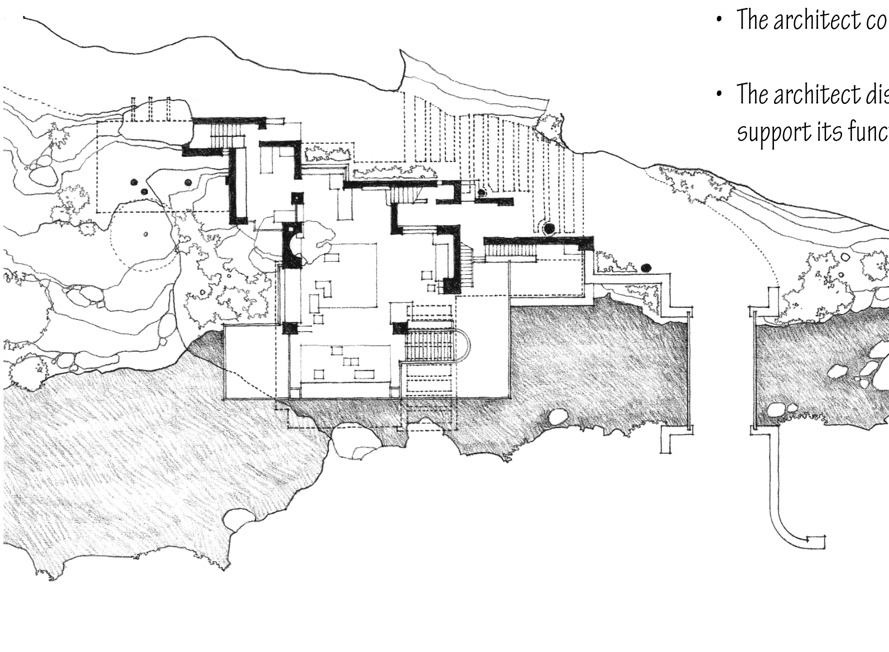
- A room requires an architect's understanding of design to be configured for a specific function.
- An outdoor space requires an architect's understanding of composition to define its edges without fully enclosing it.
- Buildings are experiential constructs. Experience is dependent on the configuration of spaces to inform the way it is perceived. This requires the architect's understanding of material, proportion, color, texture, and the way environments are sensed.

Designing Buildings

The first understanding of the role of the architect is at the scale of building. Buildings have specific purposes and must be organized to fulfill those purposes. The architect also has the obligation to configure spaces within the building and to position the building within its surroundings. Both of these influence the success of the building in fulfilling its designed purpose.



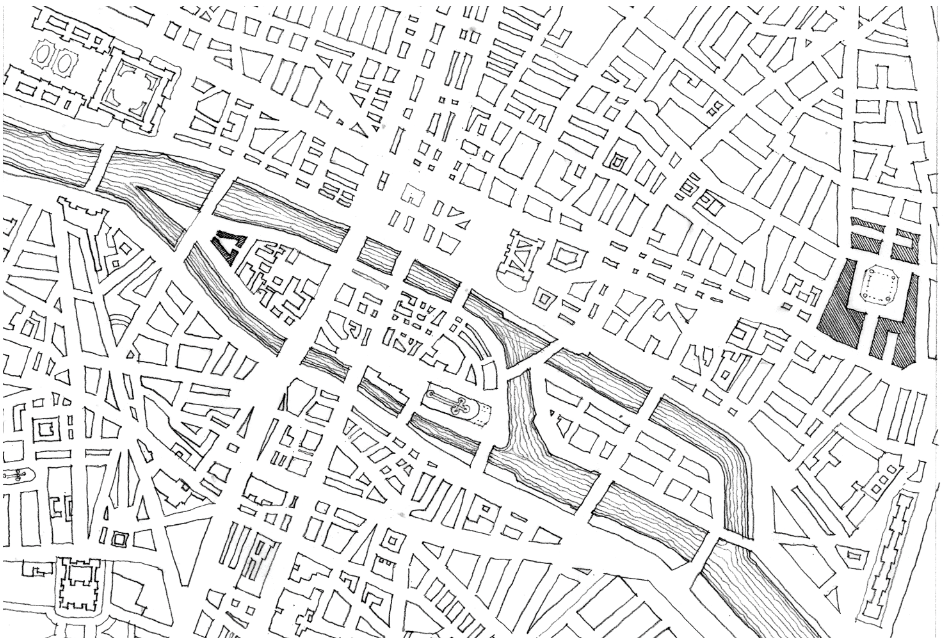
Fallingwater (Kaufmann House), Bear Run, Pennsylvania, 1936–1937, Frank Lloyd Wright



- The architect positions a building on its site to define relationships with the buildings around it.
- The architect configures a building for a specific function.
- The architect distributes spaces within the building to adequately support its function.

Designing Cities

Cities share many of a building's characteristics. They are spatial constructs, experiential environments, and designed with specific functions in mind. These similarities place the architect in an ideal position to influence the design, growth, and development of urban environments. Architects are also responsible for the buildings that compose a city, and through their design they can affect the urban environment directly.



- The design of space is the specialty of architects and is applied at the scale of cities for the development of public space and streetscapes.
- Buildings compose a city, placing architects in a position to define the development of the city.
- The zoning of a city determines the relationship between its various functions, requiring an architect to understand programmatic relationships.

Plan of seventeenth-century Paris

Walter Burley Griffin's plan for Canberra, Australia, 1912

Allied Disciplines

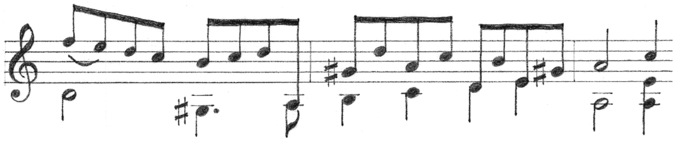
Architecture is a very old and multifaceted discipline. It touches on many subjects that influence the way we live.

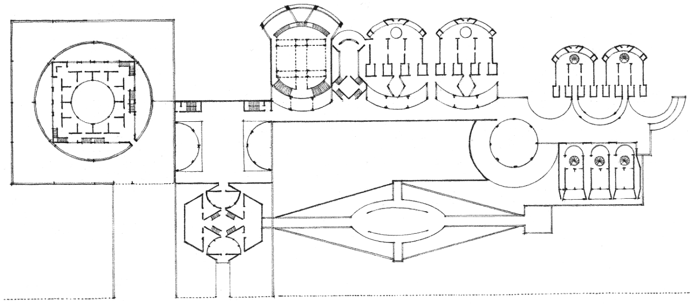
Architecture is a fine art. It shares many of the same compositional principles that are applied to painting, sculpture, music, and literature. Through those principles of design and composition, it is allied with the other artistic disciplines.

It is also responsible for creating products that work to facilitate the way we live. This aligns architecture with other design disciplines such as interior design, urban design, and industrial design. With their emphasis on inhabitable environments, interior design and urban design are historically rooted in architecture.

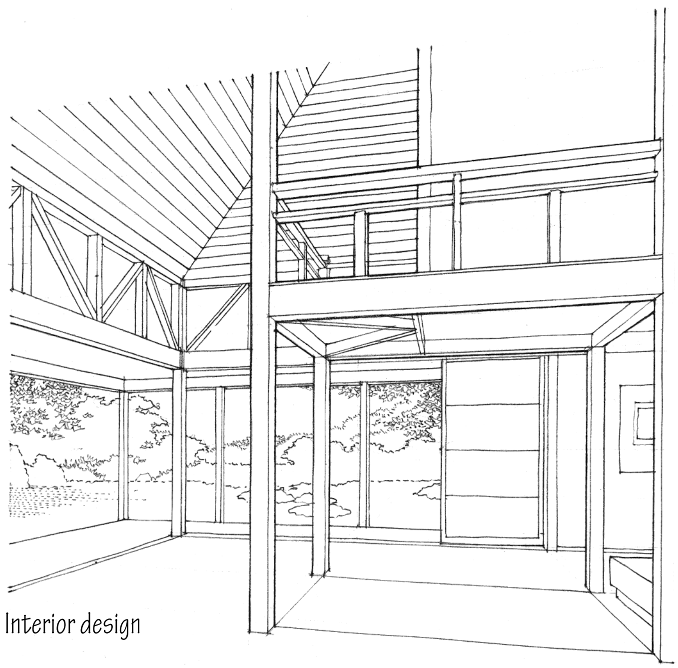
Architecture is also a construction-based science that employs a knowledge of form and material to realize buildings and predict how they will act under stress. This allies architecture with the various construction industries and physical sciences. It also employs knowledge of human behavior, perception, and culture to create spaces that support the way of life of those who inhabit it. This allies architecture with the social sciences.

Architects must have a general understanding of these allied disciplines even if they are not experts. This knowledge plays a crucial role in determining the success of a building. It enables the architect to make functional, humane designs that positively affect our ways of life.

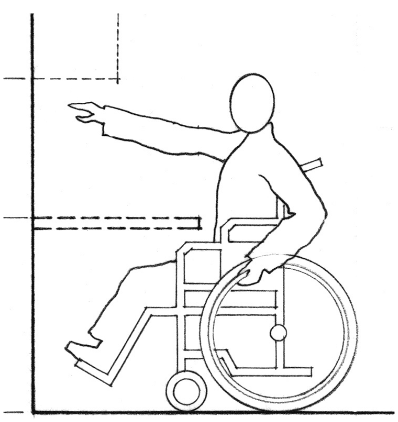




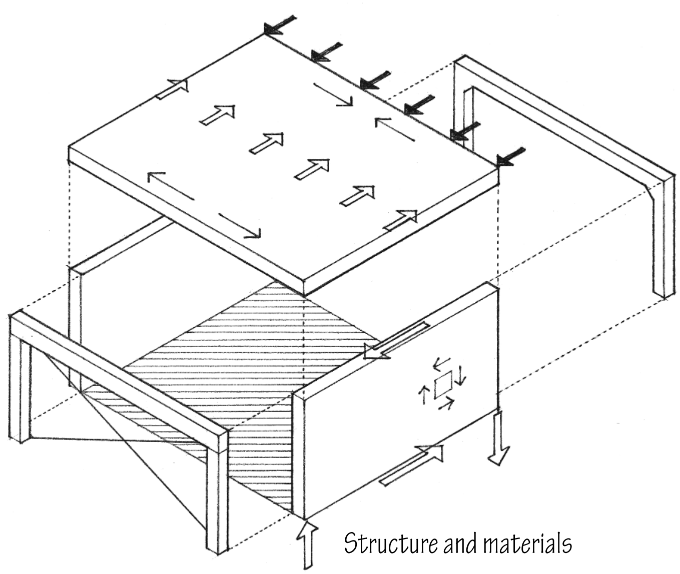
Project for the capital complex of Islamabad, Pakistan, 1965, Louis Kahn



Interior design



Human factors



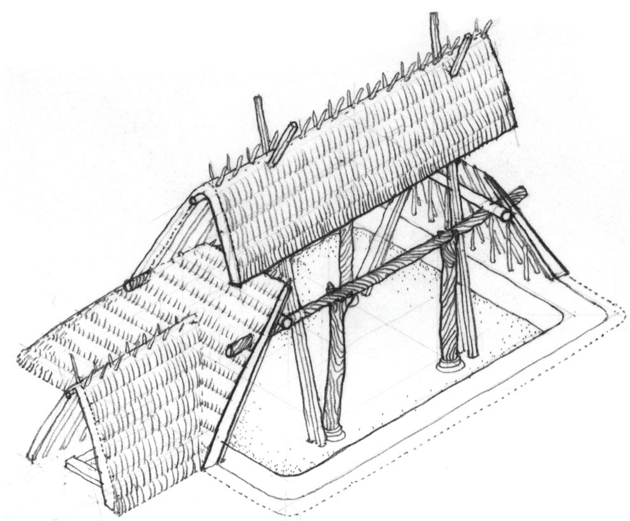
Structure and materials

The Anatomy of This Text

This text is intended to provide a brief overview of the issues and practices of architecture. It is a very old, complex, and diverse discipline, and the subject matter of this book presents only its most basic aspects.

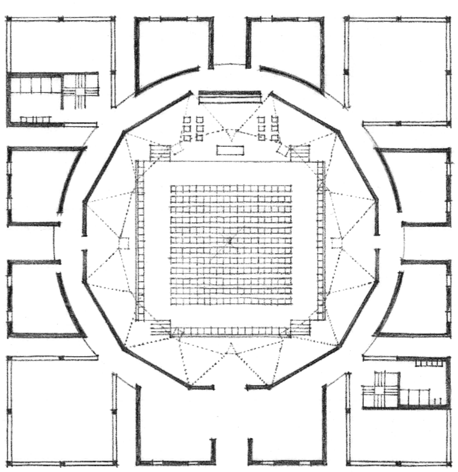
The format of this book follows the distinction between episteme and techne as described previously. The first chapters of the book are dedicated to the histories and theories of architecture as well as design elements and process. The second portion of the text is dedicated to the technical aspects of the contemporary profession of architecture.

Even within these subsets, however, one can see the interrelationship between the knowledge and craft of building. It is not possible to divide the two facets of architecture. In the first portions of the text, which detail design concepts and process, it is not possible to remove the aspects of craft and knowledge upon which those concepts are built. Similarly, in the later chapters, which detail technical aspects of the profession, it is not possible to completely remove the artistic desire from the act of construction. For that reason, one can understand the book's structure as a division between design thinking and design execution, knowing that neither is ever isolated from its artistic or academic foundations.

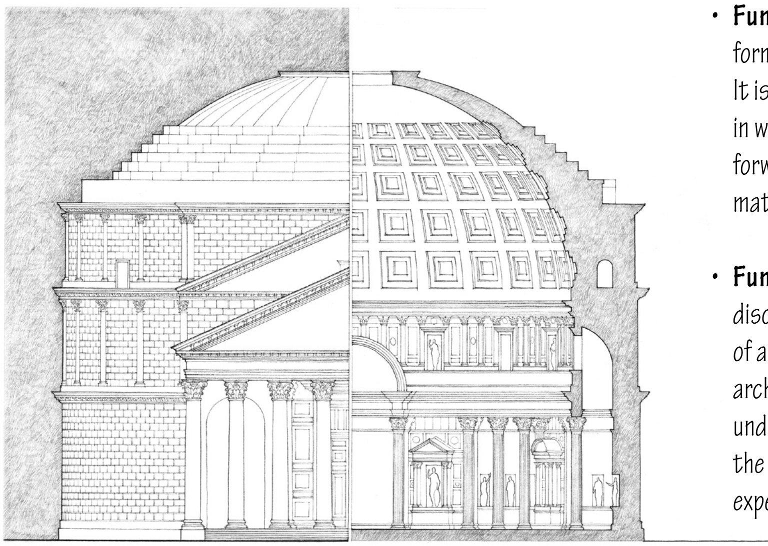


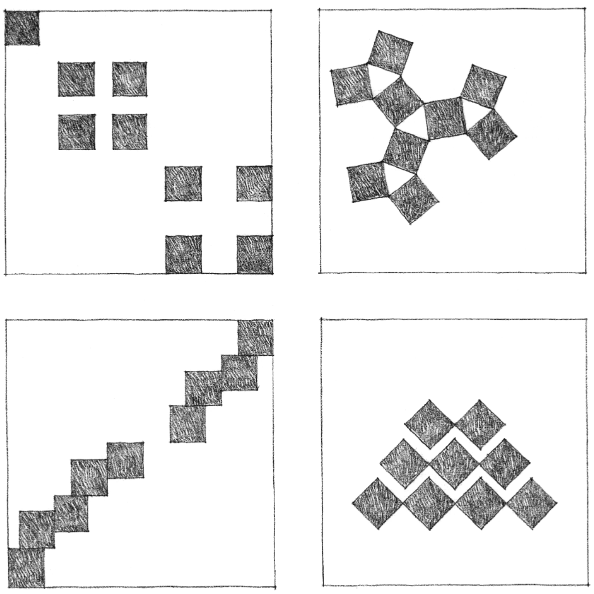
The chapters that detail architectural design thinking are:

- **Origins of Architecture**—Chapter 2 addresses the ancient history of architecture. It looks at the formation of the discipline and the factors that motivated its early development. Rather than providing a specific history, this chapter focuses on the events that surrounded and motivated the earliest developmental stages of architecture.



- **A Concise History of Architecture**—Chapter 3 addresses the history of architecture from the Renaissance to the contemporary period. It also focuses on the different global events that shaped the profession as opposed to supplying a detailed historical accounting.





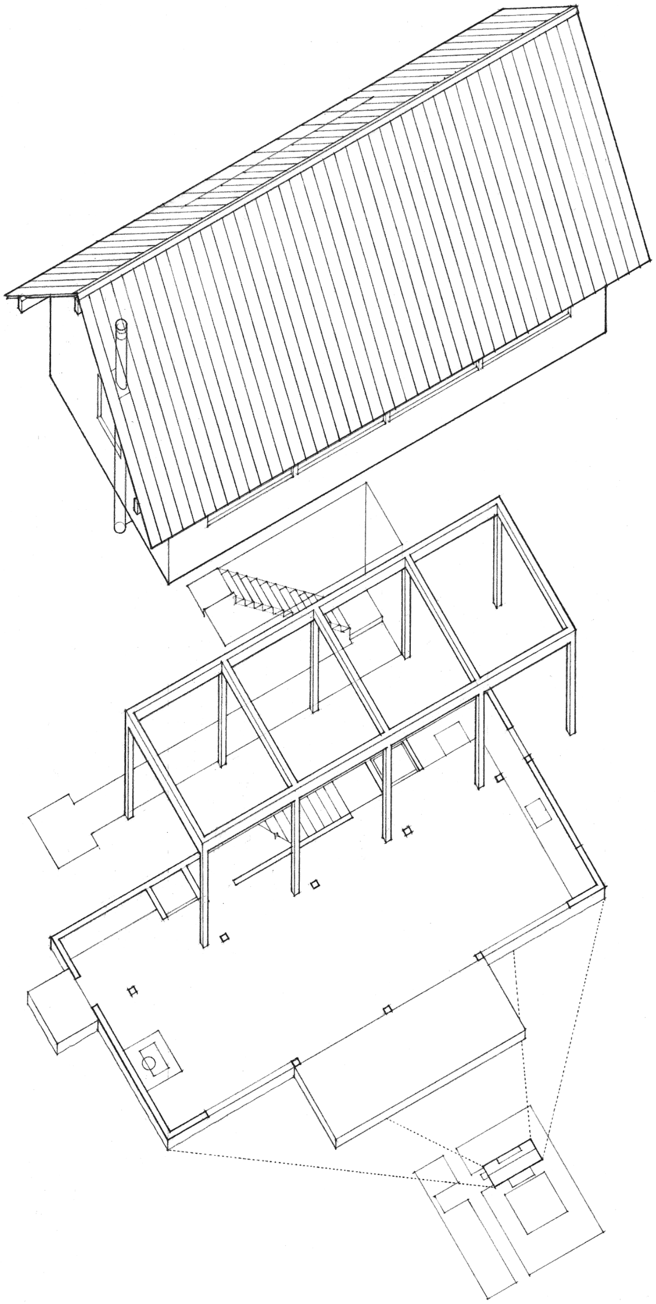
- **Fundamentals of Architecture: Form**—Chapter 4 discusses form as one of the fundamental design considerations of architecture. It is the physical nature of architecture. This chapter details the ways in which it is understood and used in the design process. It also looks forward to the way formal thinking prefigures an understanding of material, construction, and other acts of making.

- **Fundamentals of Architecture: Space**—Chapter 5 discusses space as one of the fundamental design considerations of architecture. It is the experiential and habitable nature of architecture. This chapter details the ways in which space can be understood and used in the design process. It also looks forward to the way spatial composition prefigures issues of programming and experience.

- **Fundamentals of Architecture: Order**—Chapter 6 discusses order as one of the fundamental design considerations of architecture. It is the organizational nature of architecture. This chapter details ways in which organization and ordering can be used in the design process. It also looks forward to the way arrangement and composition of architectural elements prefigures programmatic relationships and spatial sequencing.

- **Elements of Architecture**—Chapter 7 discusses the elements that comprise architecture. It looks at the anatomy of a building and different ways in which different elements can be combined to spur innovation as a part of the design process.

- **The Design Process**—Chapter 8 discusses the design process as the primary means by which an architect generates design ideas about a project. It looks at considerations of the design process; it also addresses the iterative and heuristic nature of design. This chapter discusses in more detail the various representation techniques and drawing types that can be applied throughout the design process.



The chapters that detail architectural design execution are:

- **Materials of Architecture**—Chapter 9 discusses the use of material in architecture. It details material as a means of affecting the perceptions of space. It also addresses the behavior of material as it is used in construction and influenced by a variety of factors that affect a building as it ages.

- **Methods of Construction**—Chapter 10 details various methods of construction and the ways in which these techniques might influence design decisions. It addresses the advantages and disadvantages of common construction types.

- **Building Structure**—Chapter 11 discusses the structural considerations of building design and construction. It addresses the forces and loads that affect buildings and architectural elements. It also addresses the behavior of common structural systems for buildings.

- **Building Systems**—Chapter 12 discusses building mechanical systems. These systems enable a building to function appropriately by providing electrical service, plumbing, and mechanical control over temperature, ventilation, and other factors that influence the interior environment.

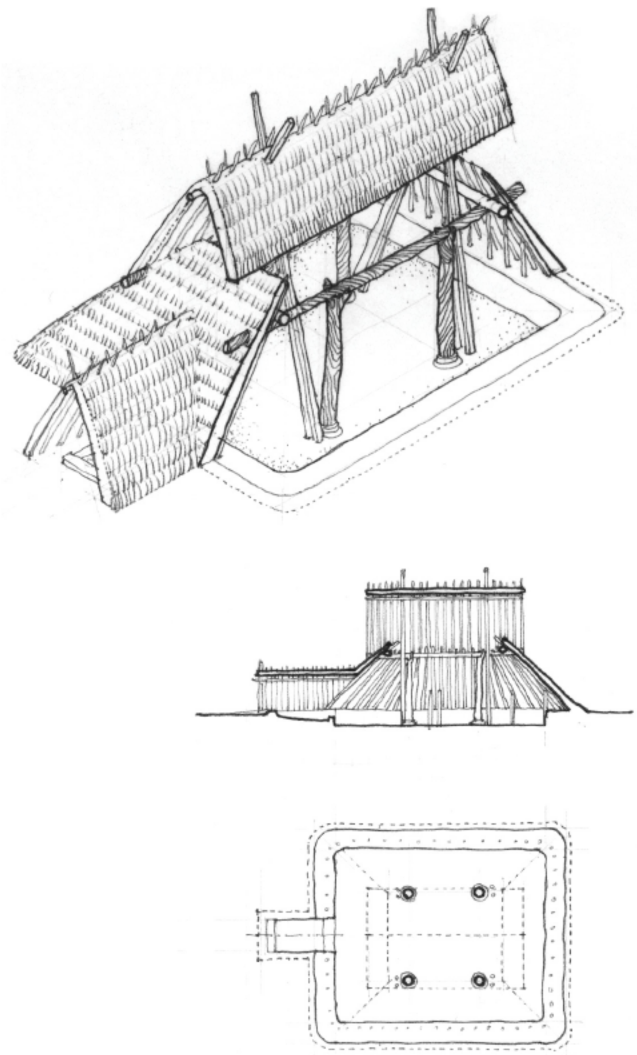
- **Architectural Practice and Communication**—Chapter 13 discusses the profession of architecture and the role of the architect in the realization of a building. It provides an overview of legal responsibility and techniques for organizing and communicating with the various members of a design team.

- **Allied Disciplines: Interior Design**—Chapter 14 discusses interior design as an allied discipline to architecture. It addresses the priorities of interior design and the way they relate or overlap with those of architecture.

- **Allied Disciplines: Urbanism**—Chapter 15 discusses urban design and urban planning as allied disciplines to architecture. It addresses characteristics of the city. It discusses the priorities of urban planners and the way they relate or overlap with those of architecture. It also discusses the influence the architect has over the development of a city and the role one might play in defining strategies for its advancement.

2 The Beginnings of Architecture:

Early History—from Ancient Times to the Renaissance



Meeting hall at Banpo, near modern-day city of Xi'an, China, ca. 4500 BCE

What Is the First Architecture?

The origins of architecture have long fascinated both its practitioners and scholars. Understanding the first incarnations of architecture helps shed light on its most basic motives. Looking back to the very first example of building one can see architecture as a tool; it is an invention intended to satisfy the most basic needs of human beings: shelter, protection, and control over one's environment. The earliest architecture teaches us what it means to dwell in the simplest meaning of the word. We see humankind's desire to not only seek shelter, but also to create a new environment according to each individual's own wants. We see the motivation to create place—architecture, even in its earliest manifestations, is something that speaks to the identity of the people who dwell within it. It is a symbol of social ties, a place for interaction.

Studying early architecture, as a result of both pragmatic demands for shelter and social demands for gathering, provides understanding of the connection between form and function.

This chapter looks at the earliest known architecture along with the events of the time that likely influenced its development and characteristics. The following is a time line of events and architectural developments that ranges from its origins to its emergence as a complex discipline addressing, not just the basic needs of shelter, but also those of society and culture. This time line begins with the events that shaped architecture in the earliest known civilizations and advances to those in the pre-Renaissance.

Early Cultures

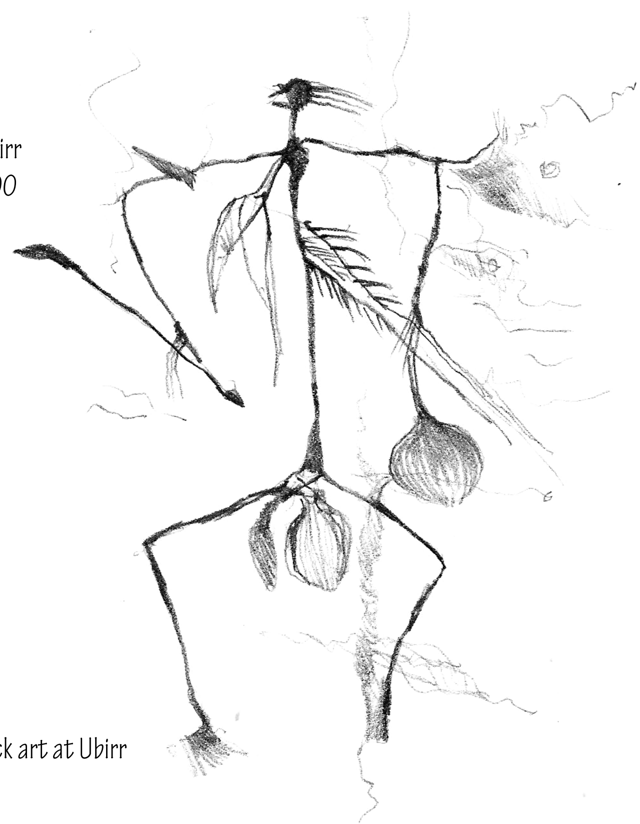
By 12,000 BCE, human beings had distributed themselves over much of the globe, having started from Africa, moving into west Asia, Europe, south and east Asia, Australia, North America, and finally, along the West Coast to the southern tip of South America. They eventually created societies of villages and hamlets near caves or along shores and streams, allowing for a combination of farming and hunting. The domestication of animals and plants followed, requiring an understanding not only of the seasons, but also of ways to hand down that knowledge from generation to generation. It is in that same spirit that the building arts and their specialized uses for religious and communal purposes began to develop and to play an increasingly important role. Whether it was using mud for bricks or mortar, reeds for thatch, bitumen as a coating, stone as foundations, or wood as post and beams, specialized tools and social specialization were essential. The results were by no means uniform. Some societies were more pragmatic than others, some more symbolic. Some emphasized granaries, others temples. In some places, the crafts associated with building were controlled by the elite. In other places, the building arts found more common expression. Architecture, like civilization itself, was born in our prehistory, and much as with the other arts was plural from the beginning.

Paleolithic human beings created animal paintings on the walls and ceilings of numerous cave sites, such as at Lascaux and Chauvet, in present-day southwestern France and northern Spain from 30,000 to 10,000 BCE.

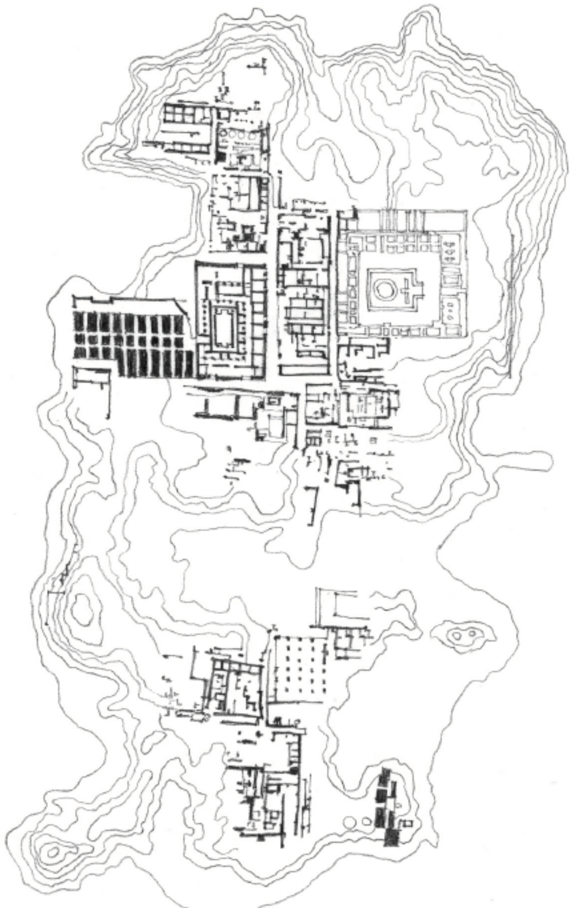
Aboriginal rock painting represents the longest continuously practiced artistic tradition in the world. The rock faces at Ubirr have been painted and repainted for millennia, from ca. 40,000 BCE to the present.

2500 BCE

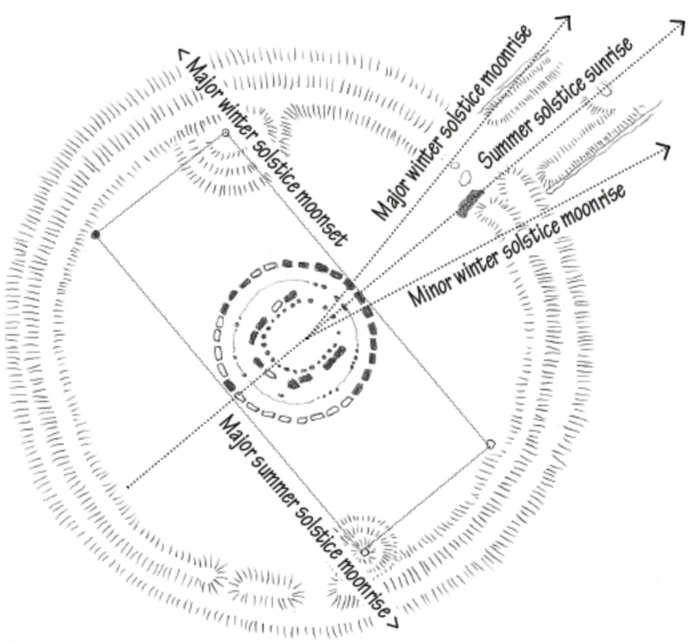
By the beginning of the third millennium BCE, the various river-oriented civilizations were primed for rapid cultural development. There were at the time five principal cultural hubs, China, Egypt, Mesopotamia, Margiana, and the Indus, which when taken together have to be understood as a supra-regional civilizational entity. Egypt was less prone to invasions by well-armed enemies and, thus, developed a consistent set of religious traditions. Furthermore, because of the seasonality of its agriculture, farm workers could be summoned by the pharaohs to perform forced labor on building projects. Zoser's temple complex, built on an unprecedented scale, was one of the first monumental stone buildings in the world. It was also a building of great complexity, answering to the intricate cosmology used by the Egyptian builders. From that point of view, the Egyptians were the first to modernize their cosmology to fit the needs of their culture and economy. In Mesopotamia, the divergent cultural elements and stretched-out trade networks made it difficult for one stable, central power to emerge. Cities, dedicated to various deities, were political entities in their own right. Irrigation canals placed a great deal of wealth in the hands of the new generation of rulers who operated in close alliance with a priestly class, ruling out of temples that were built as artificial mountains, rising in colorful terraces above the plains from the center of cities. Unlike in Egypt, the Mesopotamian irrigation system was more difficult to maintain and required greater coordination.



Aboriginal rock art at Ubirr



Upper town of Mohenjo-Daro, ca. 2600 BCE



Reorientation of Stonehenge by the Beaker People, ca. 2300 BCE

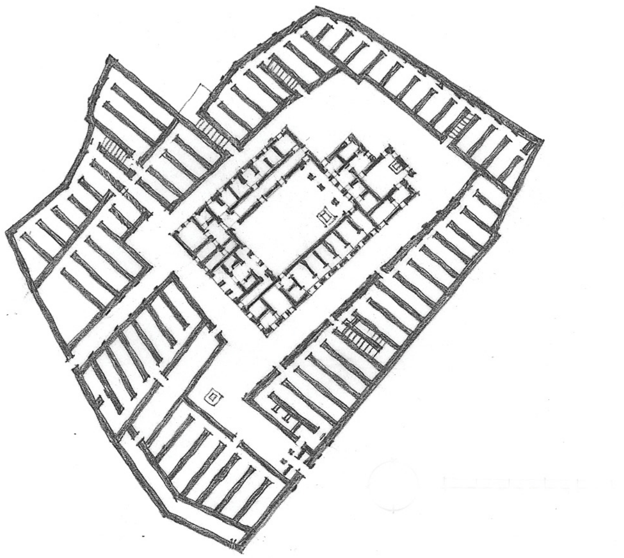
The trend to urbanization also took place along the shores of the Indus and the Ghaggar-Hakra rivers. The cities built there were particularly sophisticated in terms of planning and water drainage. Instead of a ziggurat or pyramid at the center of the town, there were huge public baths, such as the one at Mohenjo-Daro. There was extensive trade with Mesopotamia, up the Persian Gulf, and with Margiana. Indeed the entire area from Mesopotamia to the Indus and from the Caspian Sea to Arabia was what archaeologists call a "zone of interconnection." This zone went up to Derbent on the Caspian Sea, where granaries and a fortified city from the third millennium BCE were recently uncovered.

The fourth civilization zone developed around the Oxus River and is known as the Adronovo Culture. It was based at first around small villages, but eventually here, too, large cities developed in today's Turkmenistan and Uzbekistan that were much more urban and socially organized than previously thought. The cities were not only of great size, but were designed with great geometrical precision. In China, the first recorded dynasty, the Xia dynasty, emerged around 2100 BCE. Nonetheless, we still find a horizontal civilization of villages and towns unified around common ritual centers.

In Europe, we see the impact of the Beaker People, whose origins are still debated, but who most likely came from either Spain or the Balkans. Known for their advanced metal-working skill, they left their traces in various locations. They arrived in England, where they encountered such sites as Stonehenge, which they took over and redesigned, orienting it to the sun rather than to the moon. While physically this was largely a matter of "fine-tuning," the cultural implications that this reorientation presupposes are imponderable.

In the Americas, the Andean population inhabited a thin sliver of a coastline between the Pacific Ocean and a desert. Although these communities could easily have become a forgotten niche culture, the currents of the Pacific Ocean, with their rich bounty of marine life, helped sustain settled life until the inhabitants learned to tame the rivers, descending from the Andes mountains by canalization and terracing. Very recently, archaeologists have dated a large ceremonial complex above the Supe Valley in the Peruvian Andes to about 2750 BCE. This discovery has overturned Andean chronology and required a redating of large-scale ceremonial architecture to a much earlier time period than had previously been thought. Large tracts of Andean sites have still not been explored and carbon-dated, so their stories remain to be told.

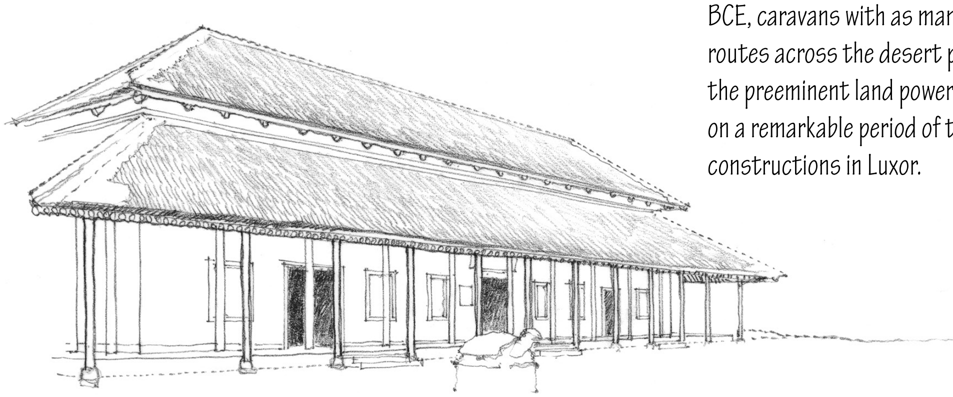
1500 BCE



Temple I at Hattusas, ca. 1800 BCE

In the middle of the second millennium, Central Asia from the BMAC society in Turkmenistan to the Indus Ghagger-Hakra region in the south went into a period of turmoil and decline. The ecological disaster of the drying of the Indus Ghagger-Hakra River certainly played a part as it created a political vacuum. During the middle of the second millennium BCE, large groups of people who called themselves "Aryas," or "Aryans," as they are now known, moved into northern India and introduced novel cultural elements. Since their structures were built of wood rather than brick, very little tangible evidence of this period of conflict and turbulence has survived. The newcomers brought with them iron and sacred oral texts that are among the oldest in the world. Around 1500 BCE, these were assembled and written down. This was the so-called Vedic period, named after the Vedas, a Sanskrit Indo-European word that means "knowledge"; this period lasted approximately to 500 BCE.

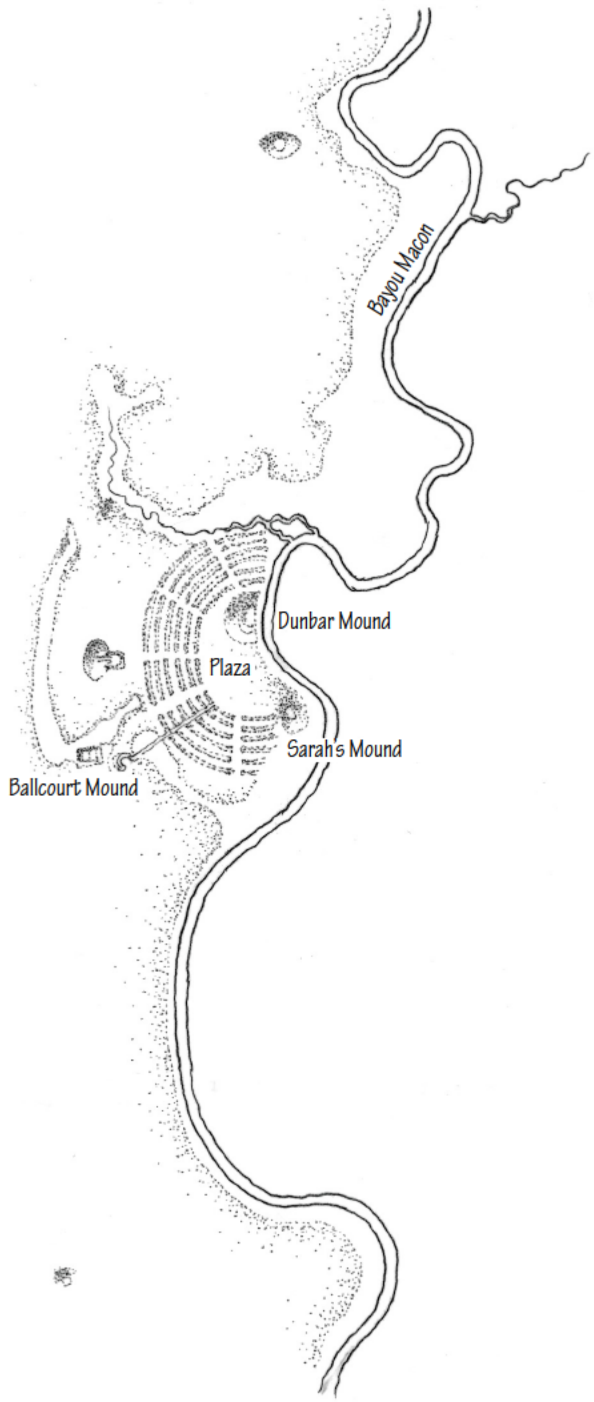
Western Asia also experienced a state of flux and instability. Assyria, Babylon, and other Mesopotamian cities were overrun by invaders of unknown provenance, the Mitanni and Kassites, who had moved in from the north and east. A similar situation existed with the so-called Sea-People, who progressed eastward along the coast of the Mediterranean conquering the Nile delta. Among the newcomers there were also the Hittites, who settled in Anatolia, where they founded a capital in north central Anatolia, Hattusas, with numerous temples. They brought in scribes from Syria to maintain their records in cuneiform script, creating voluminous state archives. They recognized the importance of the camel as a beast of burden so that, by the middle of the second millennium BCE, caravans with as many as 600 animals were plying the trade routes across the desert plains. The Hittites and the Egyptians became the preeminent land powers in Western Asia, with Egypt embarking on a remarkable period of temple architecture epitomized by the constructions in Luxor.



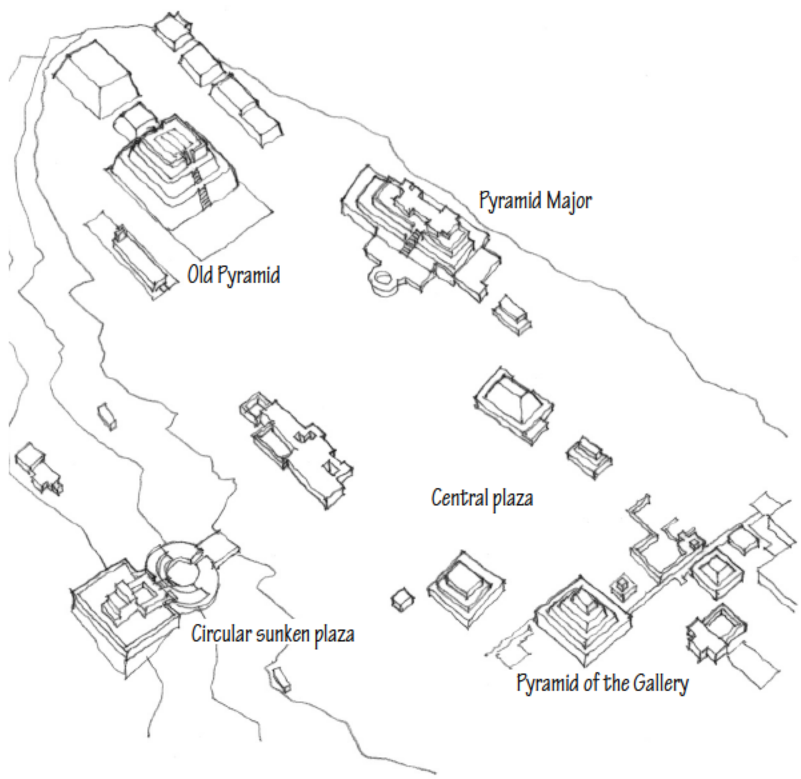
Reconstruction of Shang dynasty palace at Zhengzhou, China, ca. 1600 BCE

In 1650 BCE, the Bronze Age Shang Dynasty in China, controlled a large area in northeast and north central China, with cities arising, such as Zhengzhou and Anyang, the former encompassing a region of roughly $1\,^{1}/_{2}$ by 2 kilometers; it was one of the largest planned cities in the world at that time. The period is noted for its extraordinary bronze vessels used to hold wine and food in rituals linking rulers with their ancestors. Chinese iron technology differed from that of the West insofar as the Chinese did not forge the metal but cast it, using multiple ceramic molds.

The region of coastal Louisiana on the Gulf Coast of North America, now called Poverty Point, emerged as the center of an important chiefdom. The inhabitants built enormous earthworks as part of an artificially constructed, sacred landscape. Unlike other Native American tribes in the region who relied only on local raw materials, the Poverty Point people developed an extensive trade network. Meanwhile, in the Andes, improvements in irrigation technology enabled farmers to move upstream, away from the ocean, expand their economies, and build large sites such as Cardal in present-day Peru. Among the numerous aspects of their agriculture, it was the development of cotton that was most revolutionary. The ritual centers that were built involved enormous U-shaped complexes, the architectural elements of which would remain part of the Peruvian architectural language for millennia. The Andeans had neither the wheel nor beasts-of-burden.

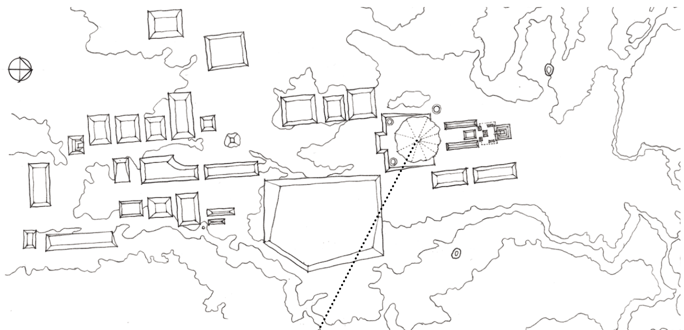


Area plan of Poverty Point, ca. 1800 BCE

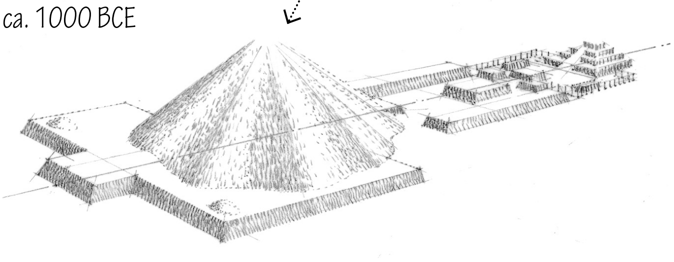


Central plan of Caral, Peru, ca. 2000 BCE

800 BCE

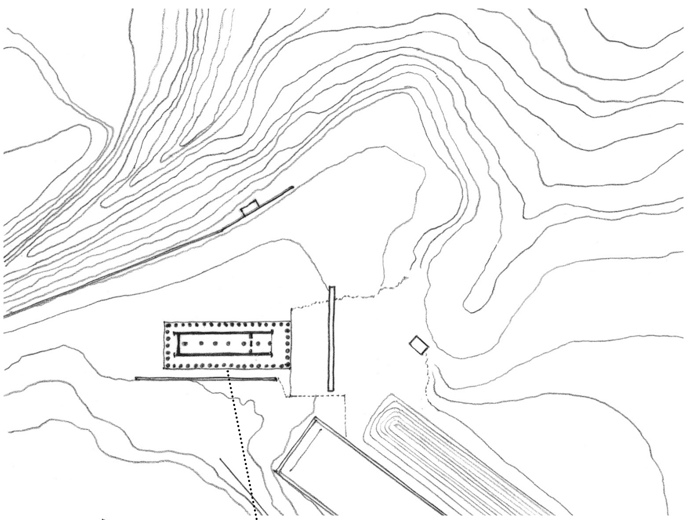


Ceremonial center at La Venta, ca. 1000 BCE

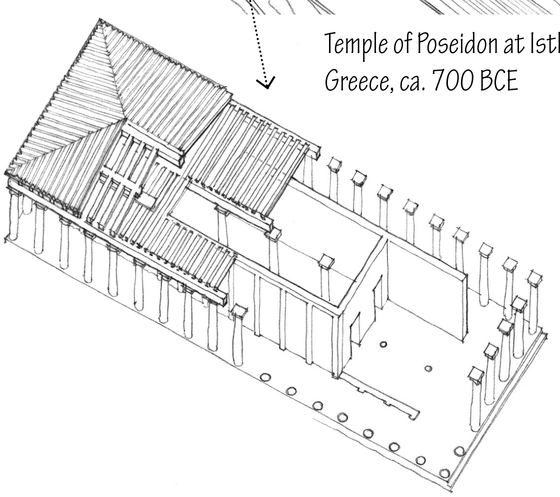


By 1000 BCE, the agricultural and water canalization techniques that had been developed in the coastal communities of South America were now also being applied in the highlands from which it was easier to control trade. Several ritual centers were founded, such as Chavín de Huántar, which was located at the intersection of important trade routes. In Central America meanwhile, the Olmecs had drained the tropical, marshy lands of Veracruz and converted them into thriving agricultural fields, yielding crop surpluses. Around this time, and probably because of Olmec ingenuity, maize or corn, which was to change the culinary world of the Americas, was developed. The resulting prosperous trading economy formed the basis for the first major ritual centers of Central America such as San Lorenzo and La Venta in modern-day Mexico.

Whereas Mesoamerica had just entered the Bronze Age, the Eurasian world was entering the Iron Age. By 1000 BCE, iron smelting had become fairly widespread, having been introduced by the Hittites. Its usage spread all the way to China. Iron weapons changed the power structure and were, presumably, the cause for much of the upheaval and displacement of the period. New cultures arose and flourished, almost all of them iron-making cultures. In northern Italy, we find the Etruscans; in Greece, the Dorians; and along the coast of Turkey, the Ionians; in Armenia, the Urartu; and in southern Egypt, the Nubians. In the eastern Mediterranean, cities such as Biblos and Sidon flourished, as did the Israelite kingdom centered in Jerusalem.

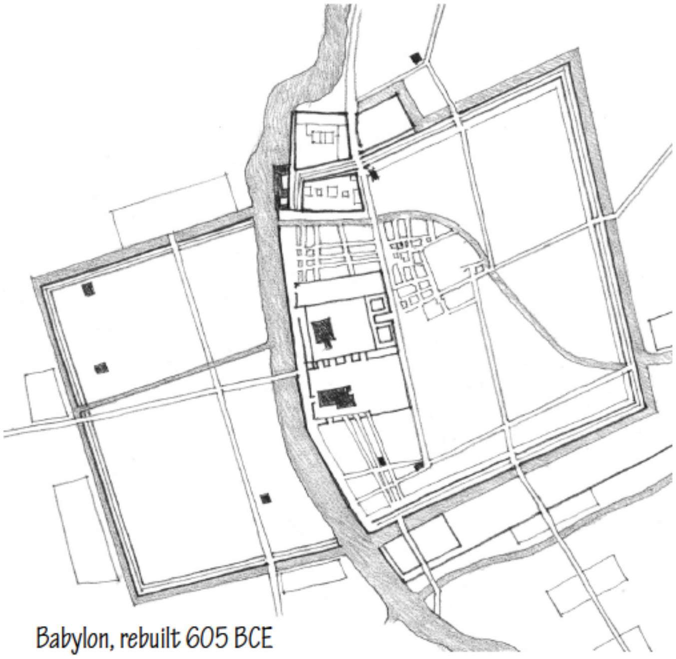


Temple of Poseidon at Isthmia, Greece, ca. 700 BCE



It was within this context of improved weaponry that the Dorians established their hold on the Mediterranean ports and extended their power toward the west by founding colonies in Sicily and Italy to secure the newly developing, grain-producing regions. Magna Graecia, as it was called, was so strong that, by the year 500 BCE, one has to view it as a single economic and cultural continuity. It was, thus, in Sicily and Italy that one finds some of the most highly developed early Greek experiments in stone architecture.

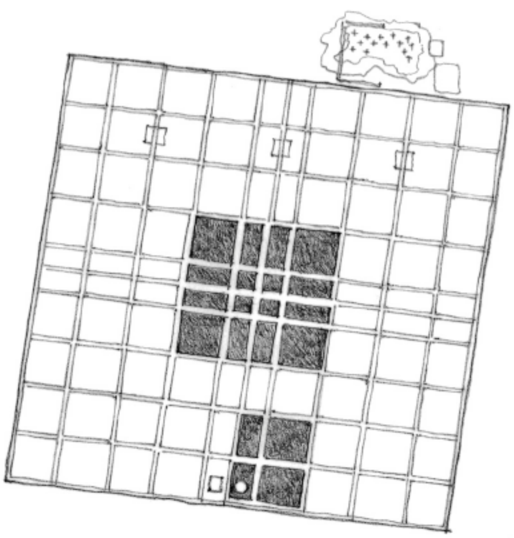
The ninth and eighth centuries saw the rise of the regional importance of Palestine in relationship to the Kush in Nubia, and the Sabaean Kingdom in Yemen. Kush was an important source of metal, and its kings for a period took control of Egypt. The Sabaean kingdom in Yemen had a monopoly on the production of frankincense, an oil that derived from a plant that grew only there. Frankincense, which was very expensive, was a requirement in many religious ceremonies. In order to reach the markets, it was brought to Palestine with its connections to ports and trade routes.



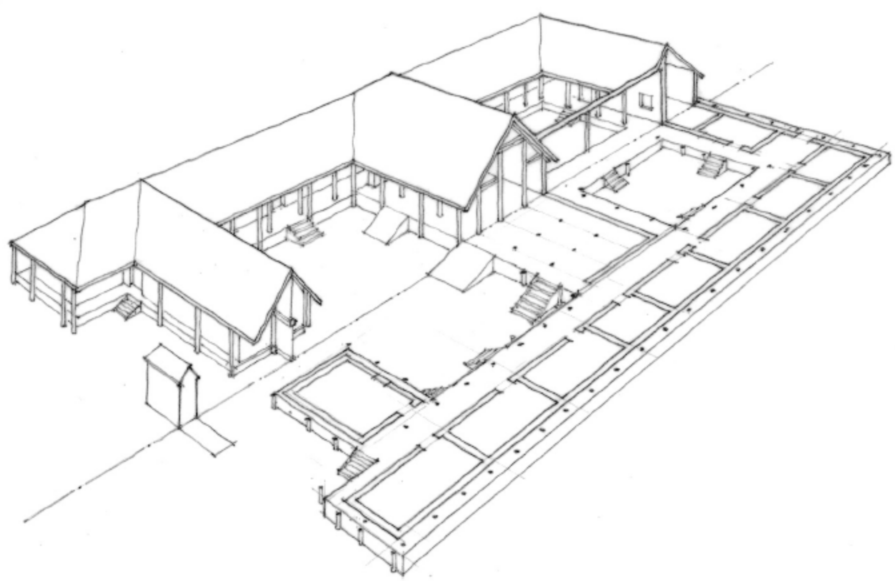
Babylon, rebuilt 605 BCE

Between the eighth and the sixth centuries BCE, the Assyrians and Babylonians established themselves as the controlling powers of western Asia, but although their empires were extensive and their new cities famous, their inability to establish coherent financial and trade policies made them vulnerable. The fall of the Babylonian Empire to Persia in 539 BCE marked the beginning of the end of a Mesopotamia-centered culture that had, for over two millennia, been one of the dominating regenerating forces, culturally, economically, and politically, in Eurasia. With this collapse, and the power shift to Persia, one could argue that from this time on East and West developed along different tracks. Further to the east, in India, the Vedic Indo-Aryan invaders, who had imposed themselves as a ruling class in previous centuries, had by this time occupied large sections of the Indo-Gangetic Plain, where they established 16 mahajanapadas, or kingdoms. Initially the state of Kashi, with its capital at Varanasi, gained supremacy, but it was subsumed by Koshala. Varanasi, however, remained an important center of learning and became home to scholars from all the mahajanapadas.

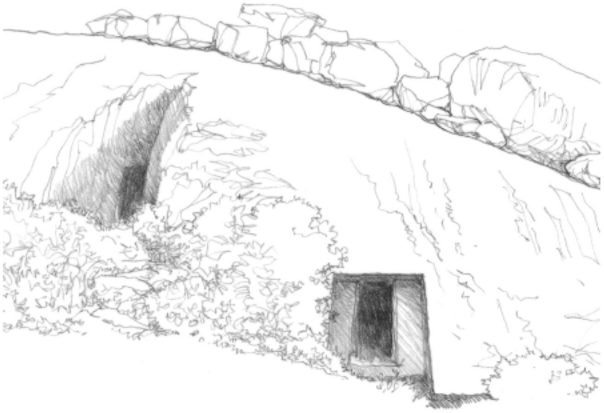
In 1046 BCE, the Zhou replaced the Shang, establishing the longest-lasting dynasty in Chinese history. They built two of China's four great cities, Xi'an and Luoyang, codifying urban planning principles that were cited, if not always adhered to, in all subsequent Chinese capital cities. Little, however, remains of these cities since they were constructed largely of wooden buildings on earth platform foundations. The Zhou created the ideology of imperial rule as the "Mandate of Heaven," which was later to be extolled as the model of governance by Confucius and others. They also began a process of consolidation, which resulted in the exile of "barbarian" tribes, mainly to the south, who became the ancestors of the Thai, Burmese, and Vietnamese.



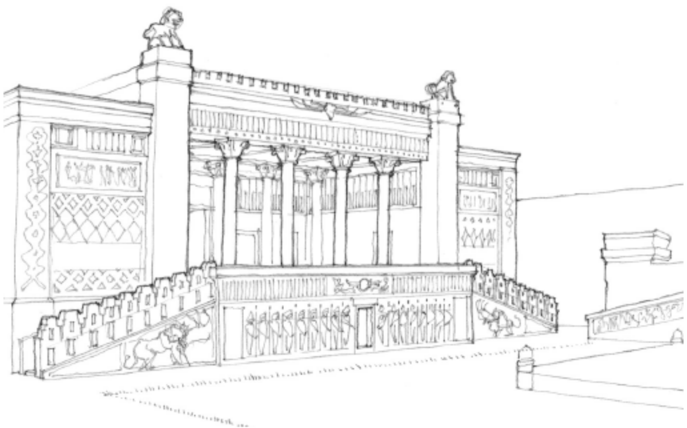
City plan of Luoyang, China, ca. 1000 BCE



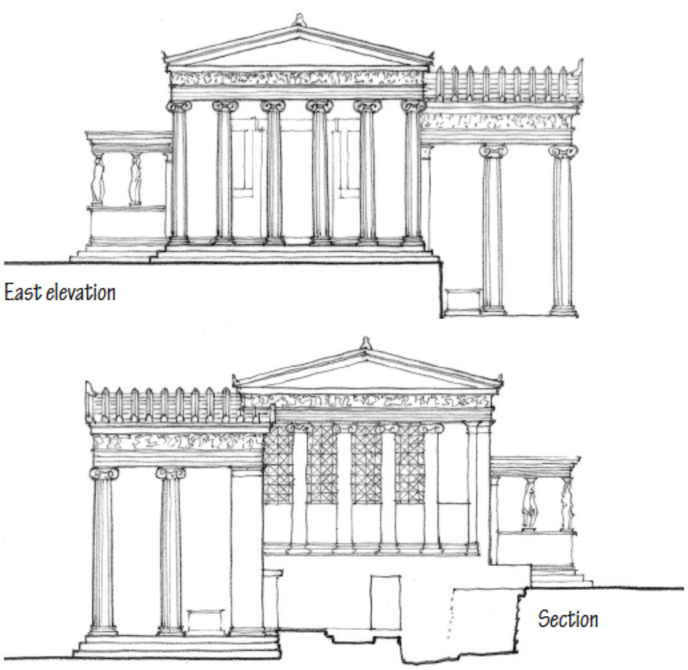
Ritual center at Fengchu, China, ca. 1000 BCE



Entrances to two of the austere Barabar Hills Caves in India, used by Buddhist ascetics, mid-third century BCE



Part of the palace complex at Persepolis, ca. 500 BCE



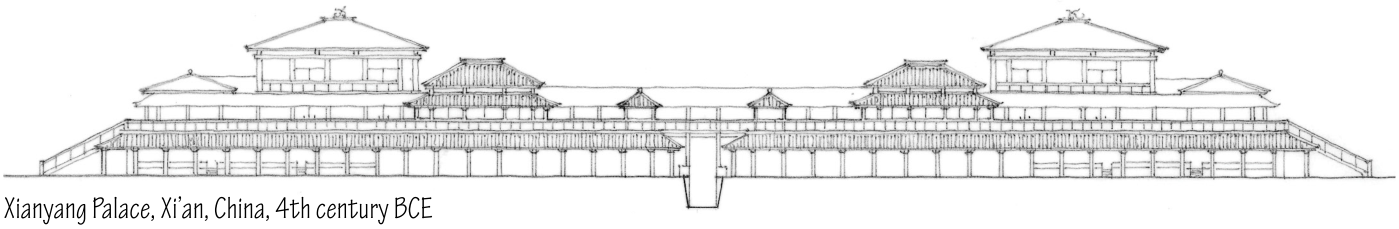
Erectheum, Acropolis, Athens, ca. 420 BCE

400 BCE

During this period, ethical and civic notions of government and of personal conduct began to take root in many parts of Eurasia. In China, for example, Confucius (551–479 BCE) envisioned a world governed by reason and proper conduct, while Daoism, which existed alongside Confucianism, stressed a sort of quiescent noninterference and the paradox of complementary opposites. In India, Buddha and Mahavira challenged the highly stratified world of the Vedic orthodoxy, emphasizing the discipline of self-abnegation. Buddhism might have remained tangential to history had it not been made a state religion by Asoka (304–232 BCE), the creator of the first empire of South Asia. Since Buddhism at the time was largely an ascetic practice, Asoka did not order the construction of large temples, but set up pillars with the teachings of the Buddha etched onto them. In Western and Central Asia we find Zoroastrianism, an ethically based religion that perceived of the world as a struggle between good and evil. Man is viewed as a potential helper of God, capable of eradicating evil. In Greece, Socrates, Plato, Aristotle, and others engaged in vigorous debates about democracy, law, and social philosophy. Athens, adopting democracy, became seminal in prefiguring the modern state. In other words, from China to Greece, religious, ethical, and social thinking was undergoing various evaluations that contrasted with centuries-old traditions that accepted the notion that power was imposed from top rather than be examined from a theoretical point of view.

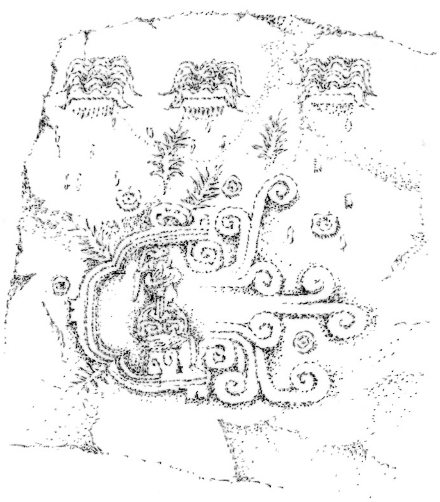
Politically, the major player in Central and Western Asia was Persia. Filling in the vacuum created by the collapse of the Egyptian, Assyrian and Babylonian empires, it extended its reach from northern India to Greece, giving rise to new architectural forms in the expansive capitals of Pasargadae and Persepolis. The Mediterranean, however, remained firmly under Greek control with the Greeks, in the fifth century, developing an architectural vocabulary that was to become foundational for European and west Asian architecture. Persia's unsuccessful attempt to conquer Greece, however, was to have unintended consequences in so far as it stimulated the fantasy and ambitions of Alexander (356–323 BCE), who conquered Persia and its territories with the help of the highly trained infantry of hoplites and their fearful phalanx fighting techniques. For a while it seemed that the Greek Empire would stretch all the way to the Indus, but Alexander's ambitions were cut short by his premature death in 323 BCE in Babylon. The conquered lands, divided among his generals, turned into quasi-independent states and regional power centers. The strongest of these was Egypt, ruled by the Ptolemies, who ruled from Alexandria. An equally important city was Pergamon in Anatolia. The tiny island trading city of Delos overtook Athens as the cosmopolitan trading hub for the Mediterranean. The aesthetic of the time, in retrospect called Hellenism, tended to realism, delicacy, and emotional expression; it left its imprint, especially on architecture and sculpture, on countries as far away as India and China.

In China, during the unstable Later Zhou period, warring regional entities competed against each other in the construction of large palaces, introducing the imperial tomb as a sign of prestige and power. By the third century BCE, the various factions were consolidated were unified by the Qin (Ch'in) Dynasty, which gave China its name.

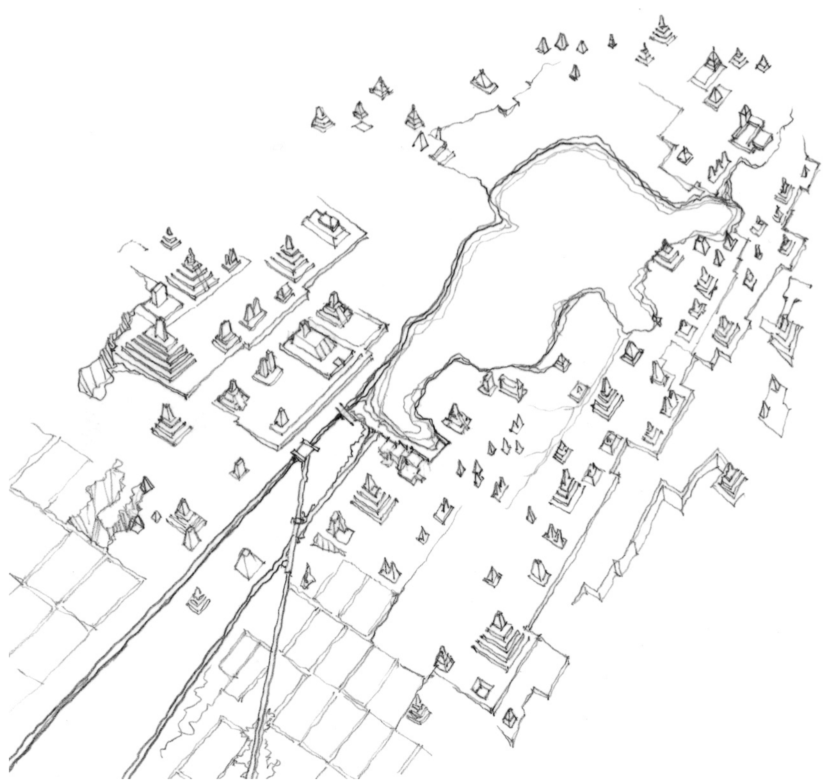


Xianyang Palace, Xi'an, China, 4th century BCE

In North America, the first complex cultures developed in the eastern woodlands along the Ohio River and its tributaries. The ground was fertile, fish and game abounded, and the waterways facilitated trade. In this environment, the people known as Mound Builders emerged. In South America, the most important cultural developments were well-organized societies that inhabited the Peruvian lowlands, the Moche civilization to the north and the Nazca tribes to the south. The Olmecs, who had been the most influential culture in Mesoamerica for some time, were in decline by 400 BCE, having been replaced by the Maya and Zapotec peoples, who were making the transition from chiefdoms to small states.



Bas-relief from Chalcatzingo, Mexico, ca. 400 BCE

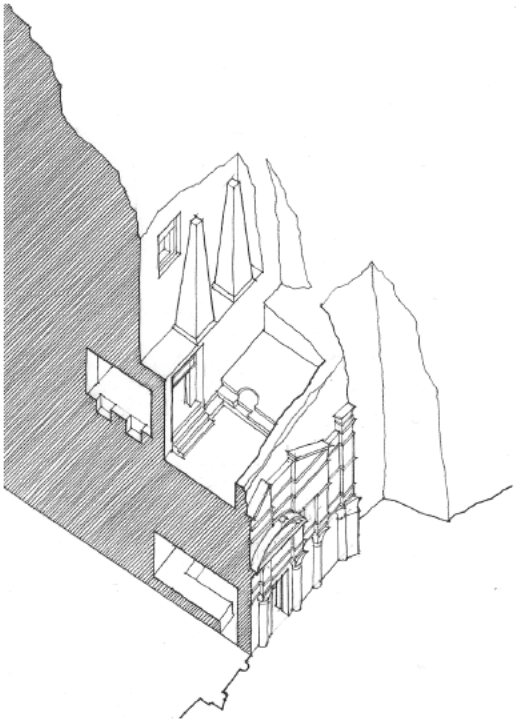


Aerial view of Kaminaljuyu, an early Mayan site, ca. 400 BCE

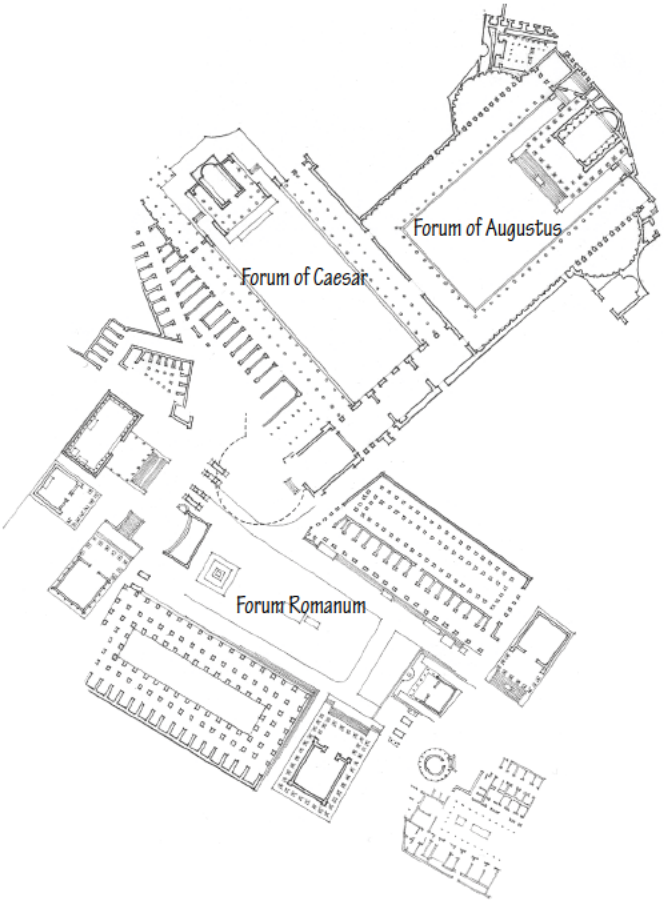
1 CE

At this time, Eurasia was dominated by China and Rome, interconnected by a vast system of land and sea trade routes, known in their entirety as the Silk Route. As a consequence of these far-flung trade-systems, two cultures in particular came into focus, the Gandharans in Afghanistan and the Nabateans in Jordan. The latter served as the connecting link to India, allowing the Roman traders to avoid Parthia. The Nabateans were remarkable for their spirit of innovation in regard to architecture.

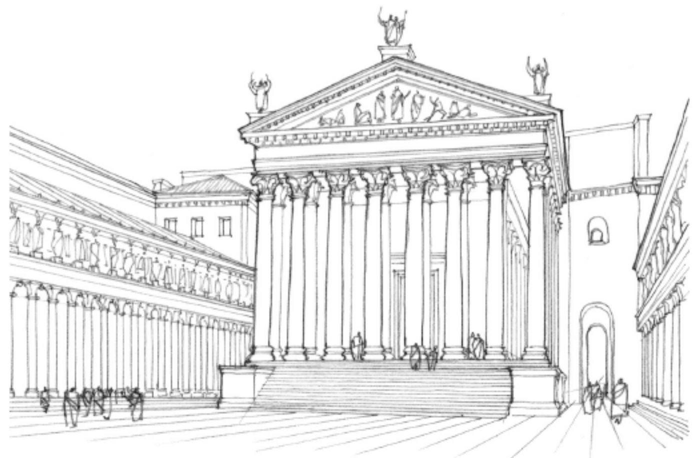
Initially, the ascendancy of Rome, in economic terms, cast a pall over West Asia and very little of consequence was built during the first century BCE. Soon, however, Rome was able to impose a cohesive appearance over its expanding domains. Roman emperors from Augustus to Trajan changed the architectural face of the European and West Asian world, building impressive temples, forums, villas, and cities, all with the typical Roman imprint.



Obelisk Tomb in Petra, trade headquarters of the Nabataeans, 300 BCE–100 CE century

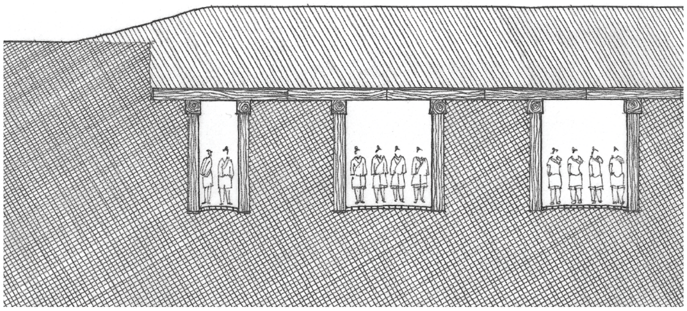


Plan of the Imperial forums in Rome, 48 BCE–112 CE

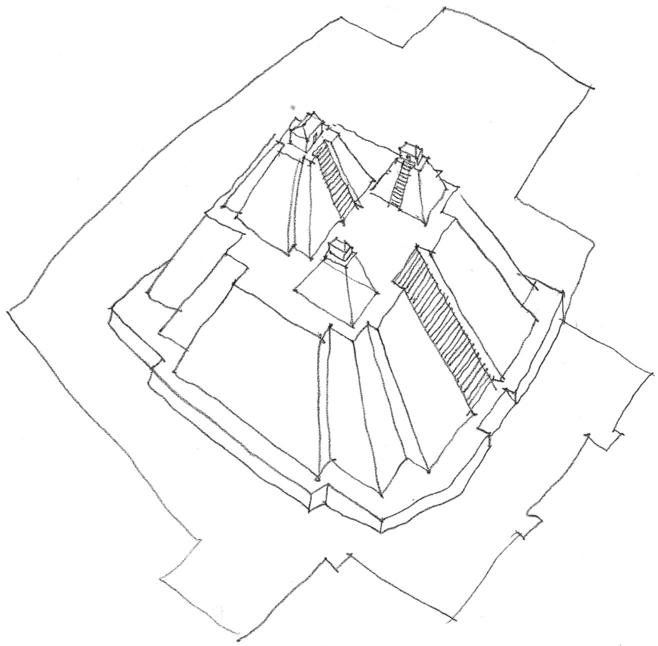


Temple of Mars Ultor, Forum of Augustus, Rome

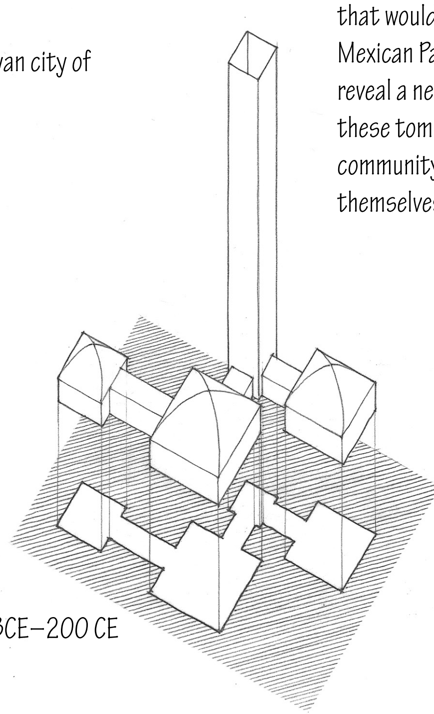
Example of a Corinthian capital



Section through vaults of the Tomb of the First Emperor, Lishan, China, 246–210 BCE



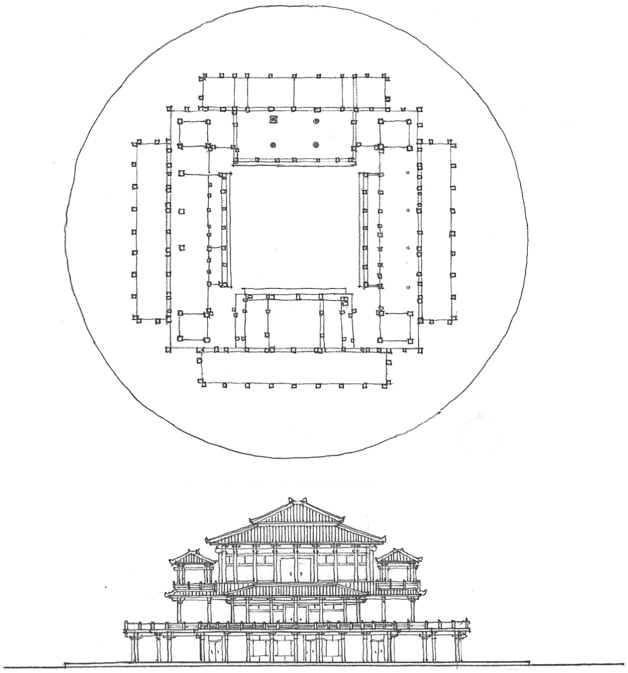
Reconstruction of El Tigre at the early Mayan city of El Mirador, 150 BCE–150 CE



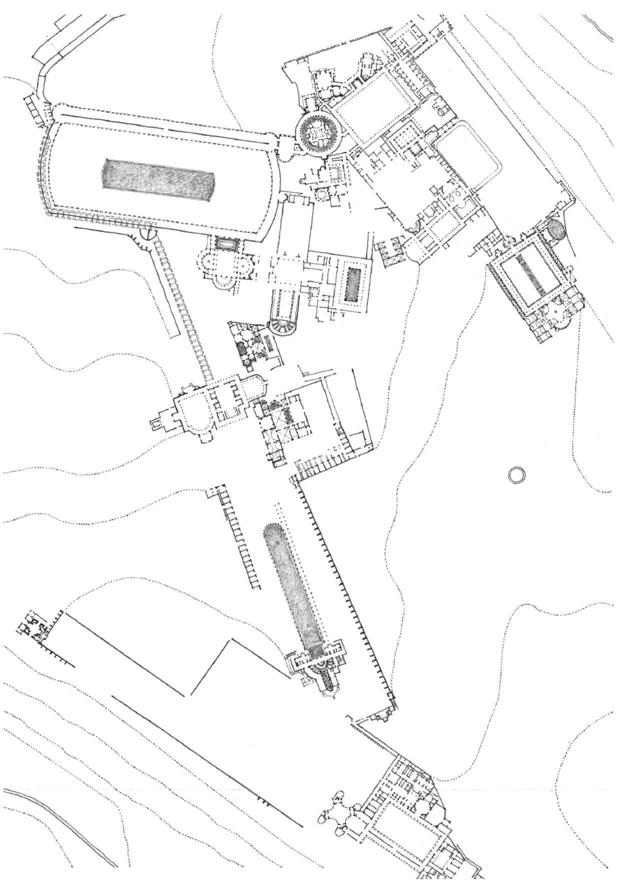
Shaft tomb at El Arenal, 300 BCE–200 CE

In China, the Qin dynasty, systematically annexing all competing states, created a centralized government with a corresponding bureaucracy. For this achievement the Qin emperor, Shi Huangdi is known as the First Emperor. It is, in fact, from the word Qin (Ch'in) that the name China derives. After Shi Huangdi's death, the dynasty quickly collapsed and was replaced by the Han dynasty (202 BCE–220 CE), which was marked by a long period of peace and is traditionally referred to as China's Imperial Age. Although more transparent and accountable, the Han maintained the Qin's ambition for a unified and centralized empire. Han architecture established precedents that were followed by subsequent dynasties. Although little remains of their actual palaces, cities, and monumental stone sculptures, clay models and literary references contain vivid descriptions, as for example those of the first century CE "spirit roads" with their stone monuments, which line the approach to imperial tombs. In central Asia, because of the disintegration of the Mauryan Empire in India, around 200 BCE, the nomadic Yueh-chi from Mongolia established the Kushan Empire (first century BCE– third century CE) that stretched from parts of Afghanistan and Iran to Pataliputra in the central Gangetic Plains in the east, and down to Sanchi in the south. Because of its unique location, this empire became a melting pot for people and ideas from India, Persia, China, and even the Roman Empire.

Looking now at the Americas, the Hopewell Culture in North America became the first large-scale culture in that region, spreading a web of cities and villages along the Ohio River. In Mexico, Teotihuacán in the Valley of Mexico and Monte Albán in the Valley of Oaxaca had rapidly risen to power. An interconnected network of villages in the Yucatan Peninsula had also begun to develop into the distinctive Mayan culture that would dominate Central American in the coming millennium. On the Mexican Pacific Coast, in the area around central Jalisco, shaft tombs reveal a new culture of death. Built into the heart of settlements, these tombs integrated the dead into the daily life and activities of the community. In Peru, the Chavin was in decline, with the pieces redefining themselves under the Moche and Nazca.



Central structure of the Mingtang-Biyong Ritual Complex, near Xi'an, China, first century BCE–first century CE



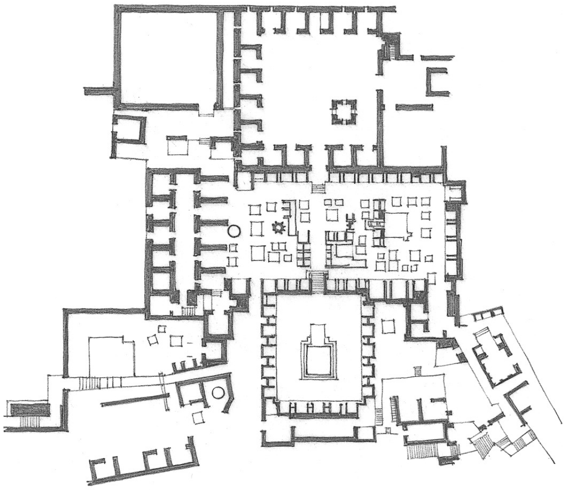
Hadrian's Villa, Tivoli, Italy, 118–34 CE

200 CE

In the year 200 CE, Rome, Chang'an, and Teotihuacán were the world's megacities; all three were the capitals of vast empires. Imperial Rome, with more than a million inhabitants, had the largest population, whereas Teotihuacán at 20 square kilometers covered the largest area. By the eighth century, however, both Rome and Teotihuacán had been overtaken by Chang'an, which had become the largest city in the world, drawing almost the entire Asian world into its economic orbit.

Between 100 and 300 CE, the Roman Empire grew into one of the greatest and most extensive empires in the world and yet was on the brink of disaster. During this time, wealth was lavished on temples, palaces, baths, viaducts, libraries, courts, streets, theaters, and amphitheaters. The development of Roman architecture, the most extensive urban architecture of any civilization to that date, reached from England to North Africa and from Spain to the Levant and would have a profound impact on subsequent developments throughout Europe and even beyond for centuries to come. The Han Dynasty was also building cities, palaces, and tombs on a colossal scale, helped by remarkable advances in technology and mining. The western capital, Chang'an, was built to serve as starting point for caravans heading westward over the Taklamakan Desert. Situated between China and Rome were the Parthians, horse-based tribal culture of former nomads, who established themselves as a ruling elite in Mesopotamia and Central Asia. They were not an architecture-oriented culture, allowing local cults to continue temple building in the Hellenistic tradition, but were keen traders and played an important part in creating the Silk Route with their capital, Hecatompylos, as one of its prime stopping places.

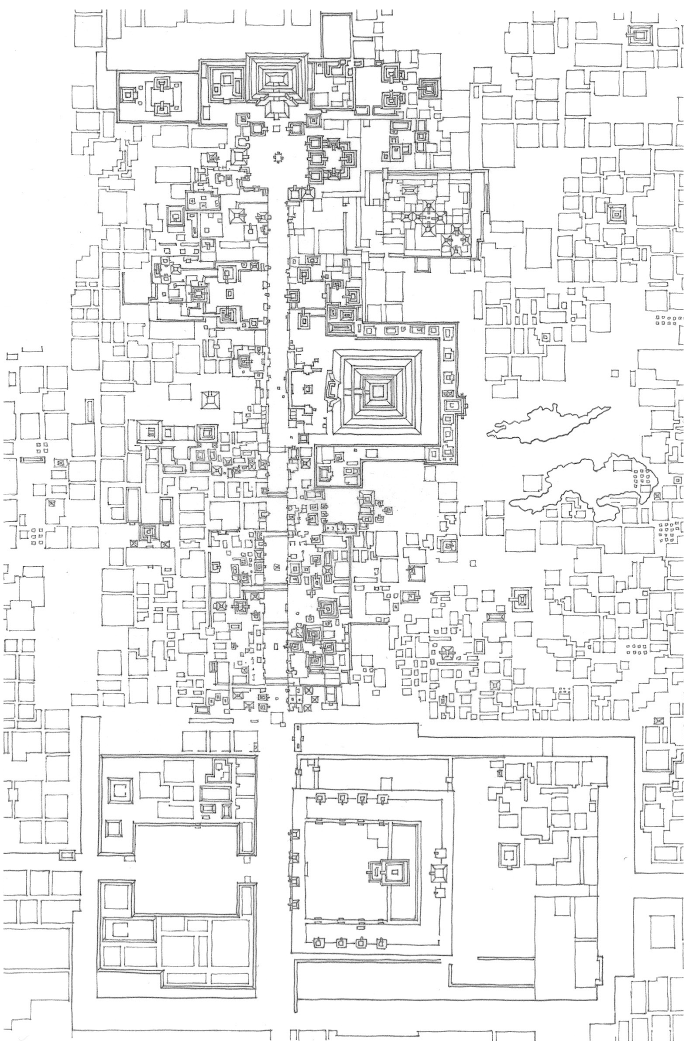
From the perspective of religion, an important transformation was taking place in western Asia with long-term ramifications beyond its geographical range. The old Mesopotamian religions were superceded by Hellenistic and Iranian mystery cults, by sun cults, by Zoroastrianism's fire worship, and by Christianity. Novel religious concepts were spreading to northern India as well, the birthplace of Buddha. Generally, these new religious practices were more personal and mystical than their forerunners. Another emerging religion was Mithraism, as practiced increasingly by the soldiery in the far-spread provinces of the Roman Empire. Buddhism, which has to be understood as part of this search for ethical self-transformation, was developing rapidly in the form of monastic schools located along trade routes moving deeper and deeper into China and Southeast Asia.



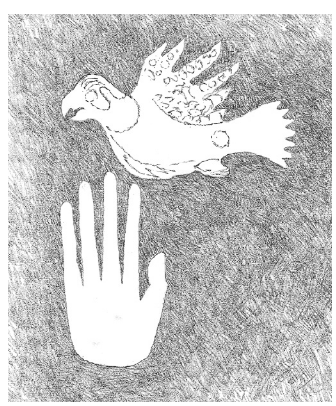
Kushan monastic complex of Takht-i-Bahi, Peshawar, Pakistan, second century CE

In the global encounter between East and West, one has to mention the Kushans, a Mongolian people that had been pushed out of China into present-day Afghanistan, supplanting the Gandharan Empire. Living at the crossroads of the region, between Persia, India, and China, and adopting Buddhism, they produced stupa complexes that were Hellenic in articulation and Indian in form, with certain elements of Zoroastrian influences. During this time, the southern maritime trade routes from Egypt by way of the eastern coast of Africa to India, Indonesia and China were beginning to develop into a trade network just as important as the land-based silk route. Like Petra in Jordan, Aksum, in modern Ethiopia, became a significant regional force trading with India and northwards with the Roman Empire.

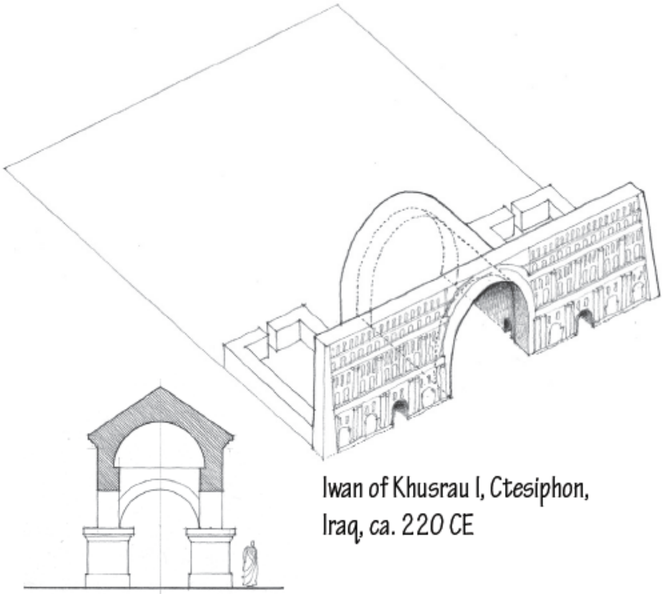
In Peru, one sees several regional states emerging, the Moche in the north and, in the south, the Nazca who produced large pilgrimage centers arose such as Cahuachi where later mysterious patterns on the ground appeared, celebrated today as the Nazca Lines. The purpose of these elaborate designs, which can only be seen from the air, remain unresolved, as do the questions about the nature of the Nazca's religious practices to which they seem related. In Mexico, the superpower of the region unquestionably was Teotihuacán, the capital of an empire that encompassed most of Central America and that was the center of a trading network that extended from the Mississippi Delta to the Peruvian coast. Teotihuacán was the largest and most influential city of pre-colonial America. All subsequent architecture in Central America was influenced by its legacy. In North America, originating along the Ohio River valley, we find the so-called Hopewell Culture, a loose confederation of tribes that shared a belief structure and burial practices not dissimilar to Poverty Point further south. They created earth works such as mounds, fenced-in hill tops, and geometrical configurations on the ground, which served as gathering places and ceremonial locations. Unlike the inhabitants of Poverty Point, they were agriculturalists with a far-flung trading network that ranged from the Atlantic to the Rockies and the Gulf of Mexico.



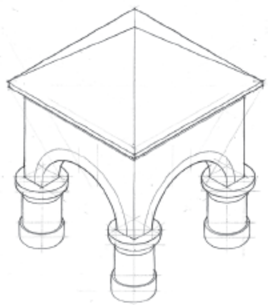
Central zone of Teotihuacán, 150 BCE–650 CE



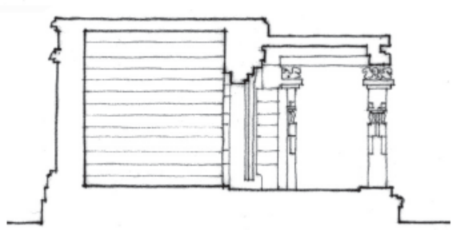
Copper falcon and mica hand, Hopewell Mound Group, 200 BCE–500 CE



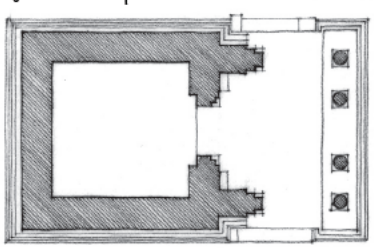
Iwan of Khusrau I, Ctesiphon, Iraq, ca. 220 CE



Possible fire temple at Ani, Armenia, sixth century BCE–seventh century CE



Early Hindu Temple 17 at Sanchi, India, fifth century CE

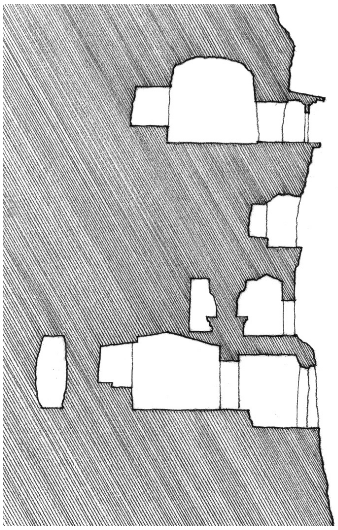


400 CE

The decline of Europe in cultural and economic terms paralleled the shift of the Roman power base to Byzantium and western Asia. The other main centers were the Sassanian Empire in Central Asia, the Gupta Empire in India, and the Han Dynasty in China. The Sassanians, replacing the Parthians and reducing the reach of the Kushanians, established their capital in Firuzabad; they ruled from the Mediterranean to the borders of China. Four hundred CE finds Eurasia in a moment of adjustment as the South Asian, Chinese, and Roman worlds were all being transformed by new religious ideas. South Asia experienced the rebirth of Hinduism, China came under the sway of Buddhism, and the Roman world was in the process of coming to terms with Christianity. Axum, in northern Ethiopia, was also still to be reckoned with, although it was by then in decline.

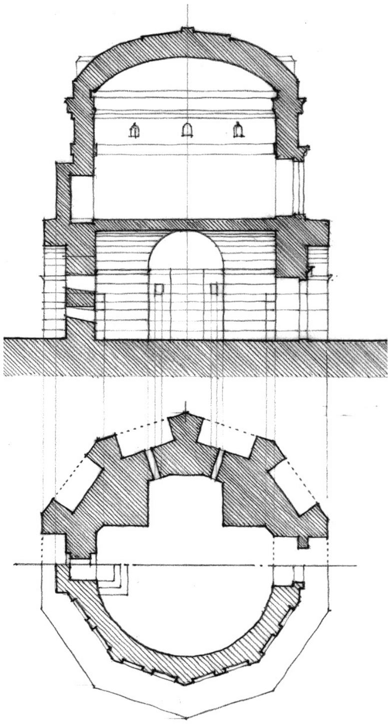
In Central Asia, the most impressive buildings at the time were made by the Sassanians in Iraq and Iran, where Zoroastrianism still prevailed. Little remains of the Zoroastrian fire temples, however, creating a gap in how we understand the history of architectural development of that time. Further east, in South Asia, the Gupta rulers had built an empire that by 400 CE controlled all of North India. They saw it as their mission to revive old Aryan theologies, but they did so in a manner that incorporated Buddhist practices. In the process, they created a new religion that we now call Hinduism. The Hindu "renaissance" under the Gupta, therefore, was simultaneous with a flourishing Buddhist practice in places such as Ajanta and Nalanda. Alongside the Gupta's first brick Hindu temples, some of the earliest Buddhist brick temple were also being constructed, such as at Bodh-Gaya, the place of the Buddha's enlightenment. Mahayana Buddhism continued to flourish in the remnants of the Kushan empire, which was located at the intersection of the Eurasian trade routes. There, colossal rock-cut Buddha figures were built that were to have a profound influence on the development of Chinese, Korean, and Japanese Buddhism.

Sheer cliff face of Bamiyan, Afghanistan, sixth century CE



Section through Mogao caves, Dunhuang, fourth to fourteenth centuries CE

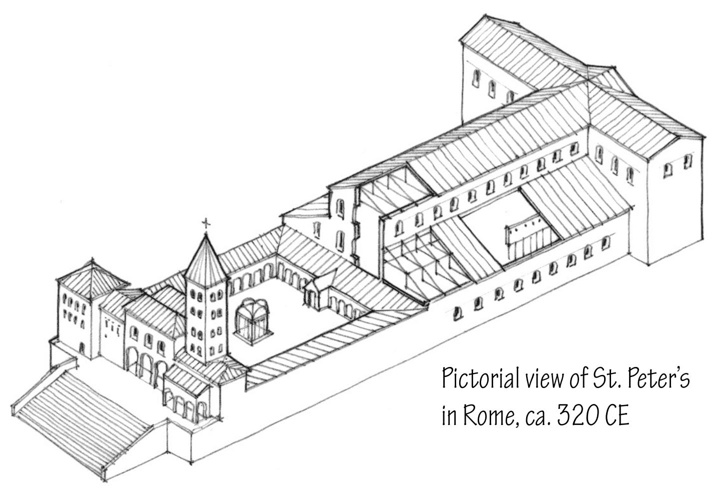
West wall of Mogao Cave 285, Dunhuang



Tomb of Theodoric the Great, Ravenna, Italy, ca. 520 CE

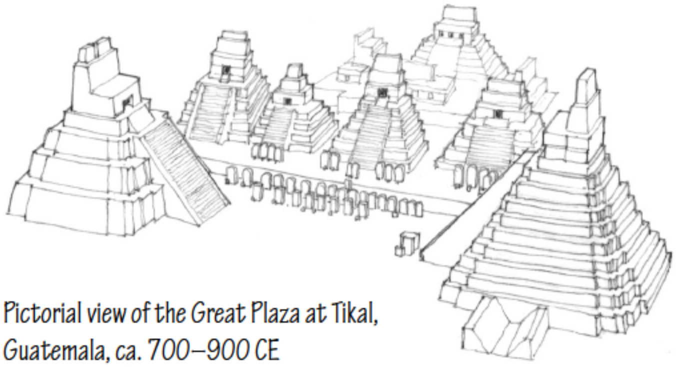
In China, the collapse of the Han Dynasty in 220 CE was superceded by the Sixteen Kingdoms, with the Chinese religious world affected by the arrival of Buddhism brought in by traders and monks from India. At Dunhuang, located at the western end of the Great Wall, where the Silk Route splits into its northern and southern arms that wind around the Taklamakan Desert, Buddhist monks built one of the largest cave complexes in the world. Hundreds of caves, carved out of the sheer cliff face, functioned as a publishing house, where thousands of copies of the sutras from India were copied for distribution throughout China. Japan, during this time, had its first encounter with centralized government, following the ascent of the Yamato clan. In a related development, Southeast Asia was on the verge of rapid expansion with Indian and Chinese traders plowing the waters in search of markets. The Pyu in Myanmar, who adopted Buddhism, were the first in Southeast Asian to develop large fortified cities built in conjuncture with extensive irrigation of local streams.

In Rome, Emperor Constantine issued the Edict of Milan in 313 CE, which decreed religious tolerance towards Christians. Constantine's city foundation, Constantinople, was, however, a hybrid of Christian and pagan motifs. The Christianization of the Empire continued after his death as "heathen" altars and temples were destroyed, and new forms of architecture, suitable for the religious needs of Christianity, were established. Architecture centered to a great extent on cities associated with great martyrs such as Rome and Jerusalem. At the same time invasions from the Russian steppes were taking their toll on the unity of the Empire, which was now split into different jurisdictions. Cities in the eastern provinces, such as Antioch and Constantinople, with their strong Hellenistic traditions, remained, however, relatively wealthy and would become for a while the key to the survival of European learning. Climate seems to have played an important role in the developments of this period. The volcanic eruption of Krakatoa in 416 CE created years of famine and disruption around the globe.



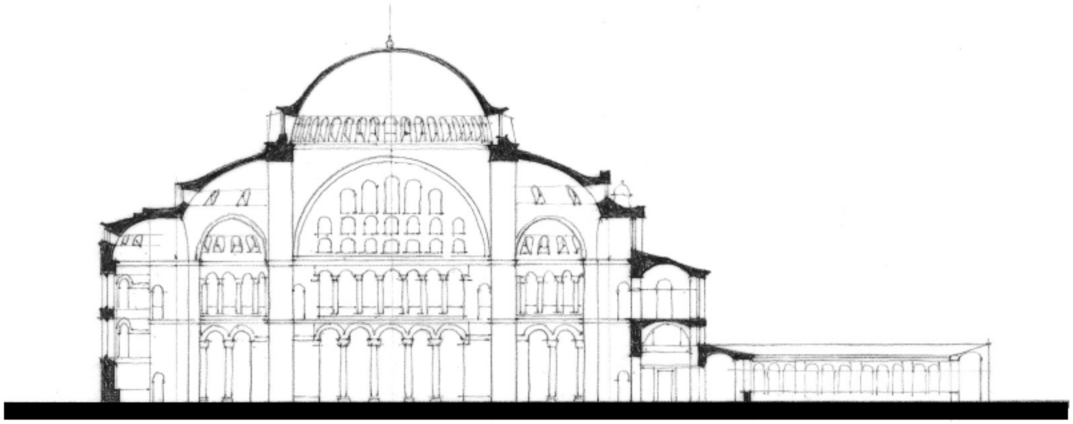
Pictorial view of St. Peter's in Rome, ca. 320 CE

600 CE

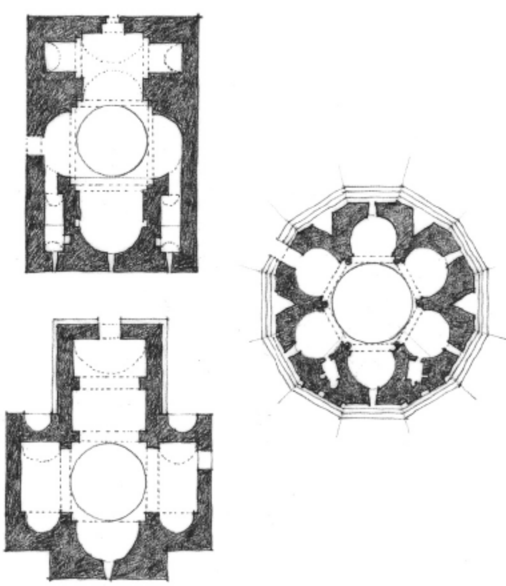


Pictorial view of the Great Plaza at Tikal, Guatemala, ca. 700–900 CE

In 600 CE, on the eve of Teotihuacán's collapse, the civilizations of Central and South America were at their zenith. With Monte Albán still a powerful state further north, a host of Mayan city-states, Tikal, Calakmul, Copán, Tonina, Palenque, and Yaxchilan, arose in the Yucatan. Although bound by trade, family ties, and a common culture, these Yucatan states competed ferociously for dominance. The main achievement of the Maya was the development of the most advanced calendar in the world. In the Andes, around Lake Titicaca, Tiwanaku emerged at the center of an extensive empire.



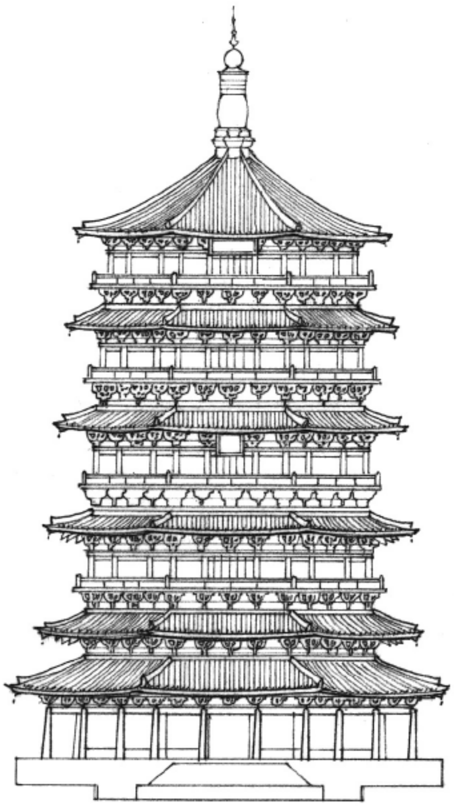
Hagia Sophia, Istanbul, Turkey, 532–37 CE



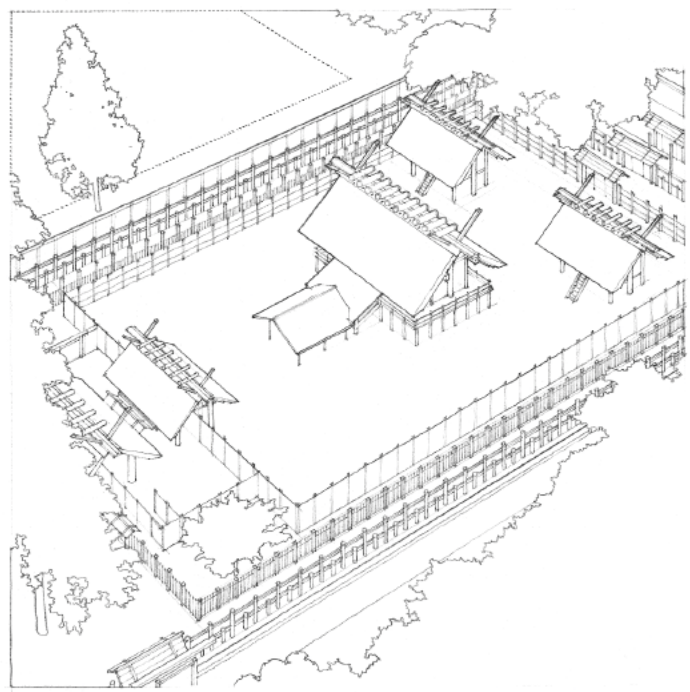
Plan examples of Armenian churches

In Eurasia, this period was a time of consolidation in which the newly arising world religions were changing and being tested. The Byzantines, for example, were in the process of adapting Christianity to establish the basis from which imperial power could draw its authority. New architectural forms were developed, such as the brick dome, concrete by this time having been forgotten. Hagia Sophia was the most ambitious and splendid architectural accomplishment of the age. The Byzantines, ruling from Constantinople, were the dominant force in the Mediterranean, but even they had to negotiate with hordes of invaders from the north and deal as best they could with Ostrogoth rulers of Italy. The plains and deserts of Syria and Persia, though still nominally under the control of the Sassanians, were in a state of unrest. Mohammed founded the last of the great modern religions, Islam, taking Mecca in 630 CE. With the Syrian heartland in turmoil, Armenia experienced a moment of growth mediating between East and West. Especially in architecture, it played an important role of cultural transmission by preserving the ancient Greek and Hellenistic traditions of fine masonry craftsmanship in contrast to Byzantine workmen who had reverted to brick; otherwise, architecture in the European West was usually made of roughly hewn stones. In the area that is now northern Syria, Eastern Turkey, Georgia, and Armenia itself, precision-built stone churches arose, with important implications for Islamic and Christian architecture in the next centuries.

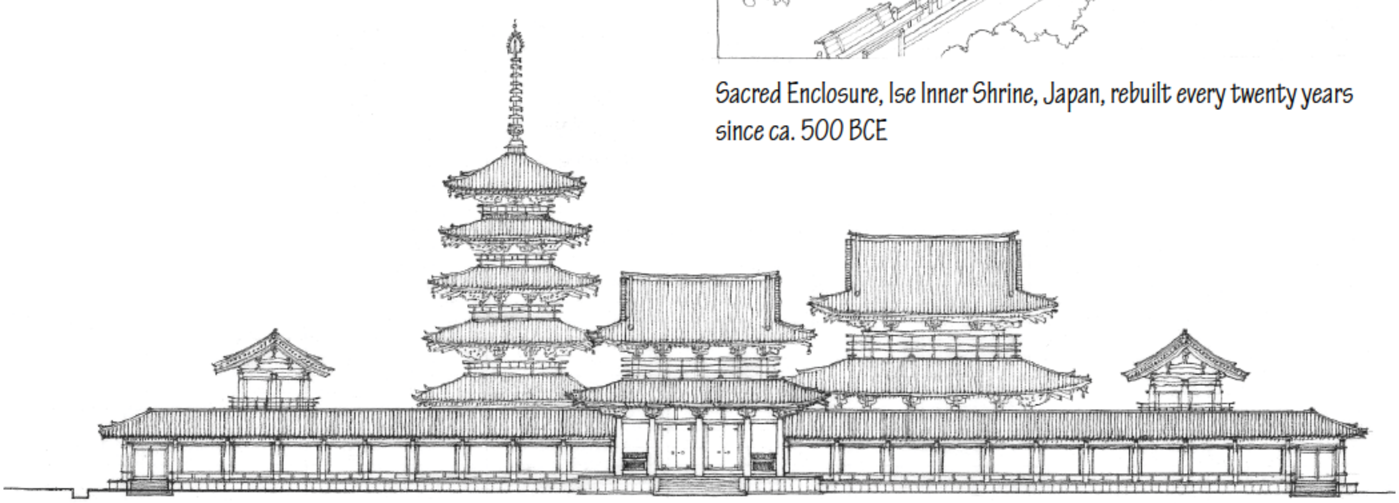
The South Asian dynasties were accelerating their transformation of Buddhism into Hinduism and engaging in experimental temple design in response to the liturgical demands of Hinduism. The Kalcuris, and then the Chalukyas in the Deccan, and the Pallavas in the south, developed a range of rock-cut and structural stone temples. While Buddhism was slowly disappearing in India, it was emerging as a powerful force in China, Korea, and Japan. The T'ang emperors invested heavily in large public work projects such as roads and canals aimed at enabling trade. As a consequence, engineering skills matured. New monasteries were built, and a new building form, the ta, or the pagoda, emerged out of the Indian stupa. Meanwhile, in Japan, Buddhism, which had entered from Korea, fused with preexisting Shinto concepts to produce a form a unique brand of Buddhism that, from the start, was allied with high architectural accomplishment, such as Horyu Temple in Nara. The first building of Ise Jingu, Japan's holiest Shinto shrine, also dates from this time.



Yingxian Wooden Pagoda, Fogong Temple, Shanzi Province, China, 1056 CE

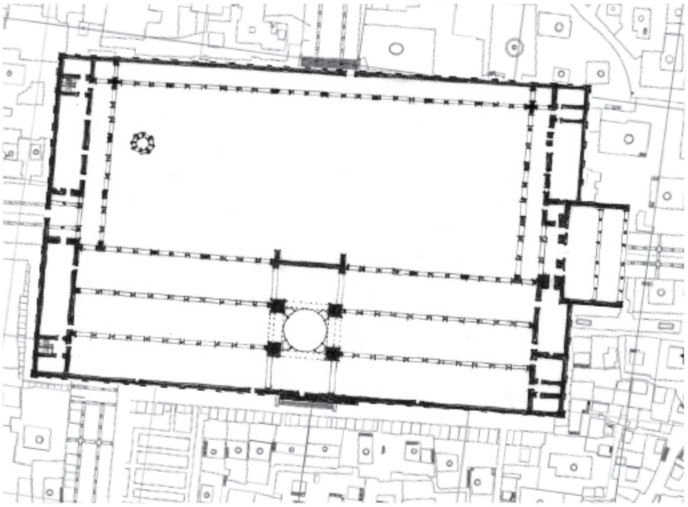


Sacred Enclosure, Ise Inner Shrine, Japan, rebuilt every twenty years since ca. 500 BCE

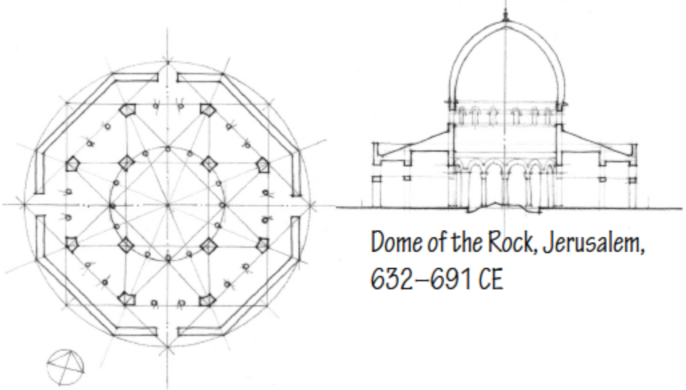


West precinct of Horyu-ji, Nara, Japan, seventh century CE

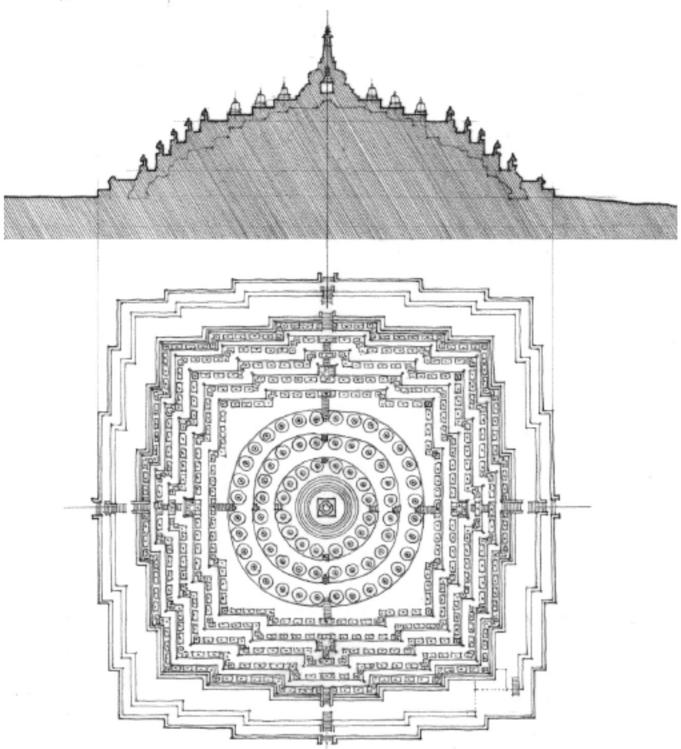
800 CE



Plan of Umayyad Mosque, Damascus, Syria 706–715 CE



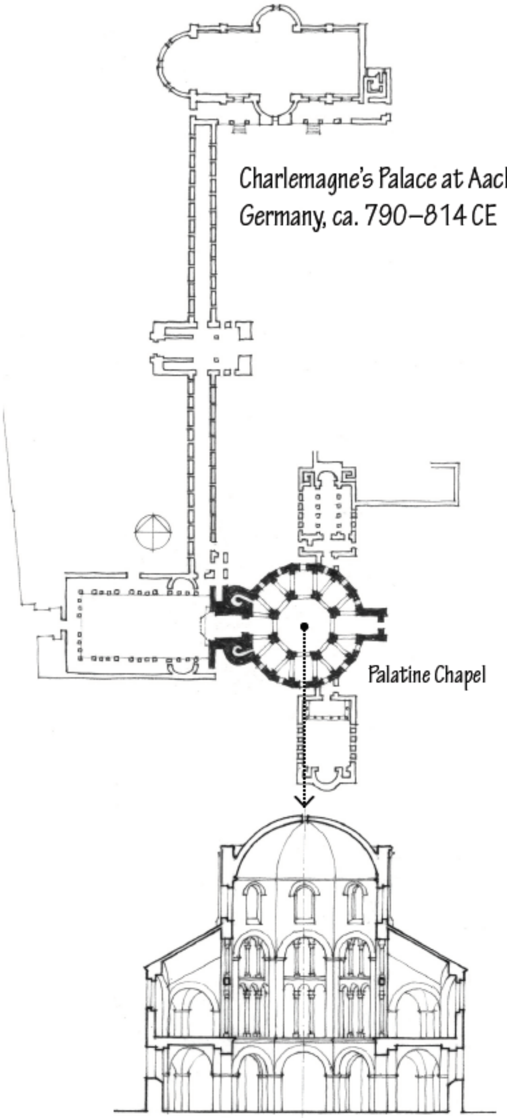
Dome of the Rock, Jerusalem, 632–691 CE



Mahayana Buddhist site of Borobodur, Central Java, Indonesia, 760–830 CE

In 800 CE, China's T'ang Dynasty (618–906 CE) was one of the largest powers in the world and the city Chang'an, at the eastern end of the Silk Road, was not only Eurasia's economic engine, but also home to a large and varied populace of different intellectual persuasion and religions. T'ang architecture, however, having mainly been of wood, has all but disappeared but for a few surviving monastic halls that afford us a glimpse of their architecture. Parallel in global importance was the new Islamic kingdom that stretched from Persia to the western Mediterranean as far as Cordoba in Spain. The architectural expression of Islam was the mosque, which in the early days of the new religion was a simple hypostyle hall oriented toward Mecca. Soon, however, more elaborate palaces and gardens arose, competing with the glamour and display of the Byzantine Empire. On the Temple Mount in Jerusalem, which had seen two Jewish temples and Roman temple, a new structure was built, the unequalled Dome of the Rock venerating the spot where Mohammed is said to have ascended to heaven. The Umayyad caliphs occupying the old Roman and Visigoth city of Córdoba in Al-Andalus on the Spanish peninsula, developed a splendid and tolerant court with a large mosque built on the ruins of a Roman Temple. In 750 CE, the Umayyad dynasty was replaced by the Abbasids, whose new capital Baghdad, made that city one of the great urban foundings of the age.

Meanwhile South Asia, divided among several kingdoms, was a hotbed of intellectual and religious activity, leaving a substantial architectural legacy. The Hindu kingdom's architects built in stone, brick and by means of rock-cutting as is evidenced by their numerous temples. Simultaneously, Buddhist monasteries continued on and matured into universities of international repute. Monks from China, Sri Lanka, Japan, Southeast Asia, and Indonesia came to study at Nalanda, Paharpur, and Amaravati. Southeast Asia was also coming into its own, fed by the expanding trade links to China and India and in particular by the Pallavas from India's east. In Indonesia, the Shailendra kings built Buddhist and subsequently Hindu stone temples of great accomplishment, including one of the perhaps finest Buddhist stupa shrines ever, Borobodur. To Indonesia's north, in Cambodia, the Khmer king, Jayavarman III, founded a new Hindu kingdom on with a capital called Hariharalaya on the flood plain of the Tonle Sap lake, the largest fresh water lake in Southeast Asia. The city, a perfect square about three kilometers on a side with a temple at its geometric center, rivaled the circular city of Baghdad as an urban founding. Having an economy organized around rice production, the Khmer were to rule over Cambodia for 600 years, their achievement largely the result of their sophisticated irrigation technology.



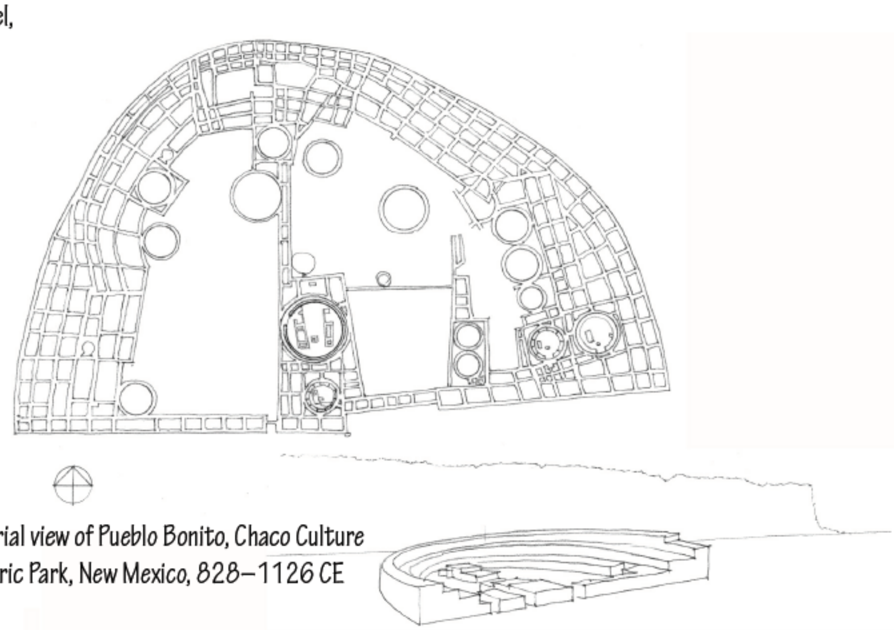
Charlemagne's Palace at Aachen, Germany, ca. 790–814 CE

Section through the Palatine Chapel, 792–805 CE

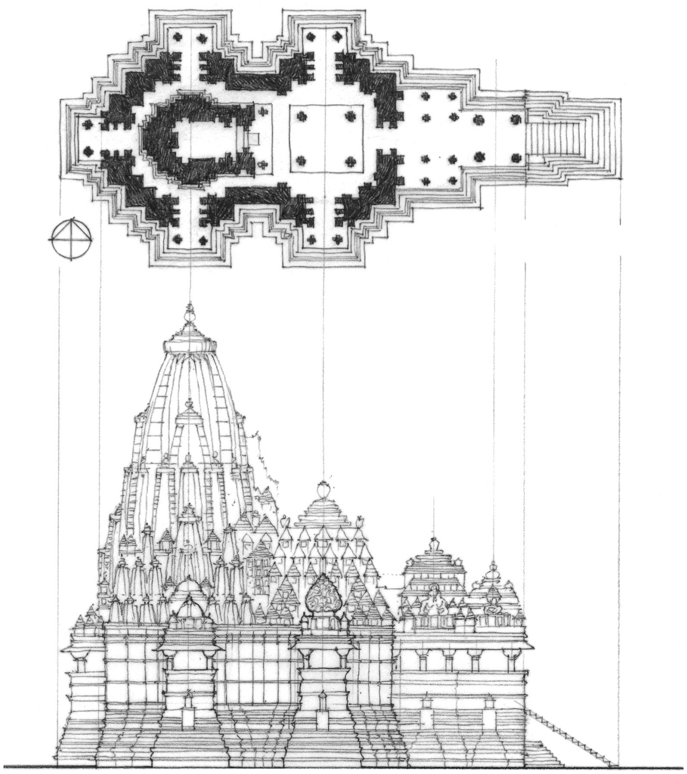
Compared to the massive amounts of wealth that flowed from East to West and that filtered its way through Southeast Asia, the situation in Europe, after the collapse of Rome, was still rather tenuous. Europe was only coming into its own when Charlemagne was crowned Holy Roman Emperor by Pope Leo III on Christmas night of 800 CE. His capacity to organize the kingdom brought Europe back into the global horizon, even though his architectural accomplishments were relatively slight, as technology and the philosophical arts were still in serious decline, and Charlemagne, though himself barely literate, admired and sponsored learning and supported monasteries, which were the repositories of ancient texts and the only source of literacy north of the Alps. Eager to assume the legacy of the Roman Empire, he adopted the language of Roman architecture that would become the referent for architectural expression for centuries to come.

All in all, in the ninth and tenth centuries, the Eurasian map started to foreshadow the modern world with distinct kingdoms arranged continuously from the Pacific to the Atlantic, linked to each other by trade and determined just as much by religion as by geography. This was also a period of urban innovation: Hariharalaya, the new capital of the Khmer; Baghdad, of the Islamic Abbasids; Córdoba, of Spain; and Aachen, capital of the Holy Roman Empire. Chang'an, however, still remained the largest city in the world along with Byzantium.

In America, a new generation of Mayan city-states had arisen in Guatemala, Honduras, and El Salvador starting around 250 CE. The impact of Central America's civilizations continued to be felt in its outermost reaches with the establishment of cities like Pueblo Bonito by the so-called Anasazi of North America.



Plan and pictorial view of Pueblo Bonito, Chaco Culture National Historic Park, New Mexico, 828–1126 CE

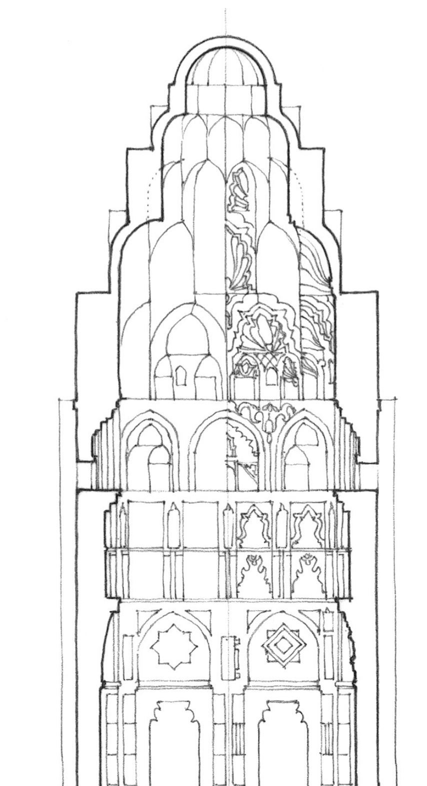


Khandariya Temple Khajuraho, India, 1000–1025 CE

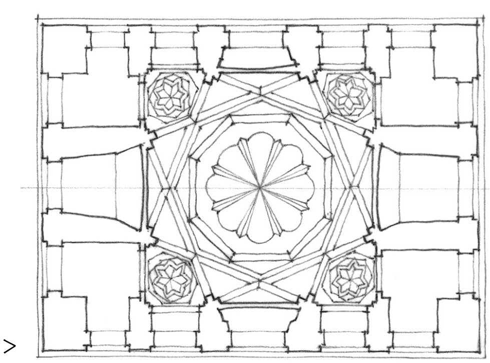
1000 CE

The turn of the millennium saw extensive temple building programs occurring throughout South and Southeast Asia. Thousands of temples arose. No single kingdom, but rather several, orchestrated this, each vying for wealth and influence. Included were older kingdoms, like the Pratiharas, and new kingdoms, like the Gangas, the Chandellas, and the Solankis. Eventually, the Cholas, in south India, would control a territory that reached from the Ganges in the north to the island of Sri Lanka in the south. The Khmer in Cambodia were building grand temples in their capital city on the Angkor plain. The Srivijaya in Indonesia were also great temple builders. All of this was to some degree a consequence of the weakening of the Silk Route as a result of political disruptions in north China that forced the Song to look to the south for economic leverage and trade. While the Song territories, crisscrossed with a network of newly established towns, developed a strong mercantile economy, the Liao in the north, who had adopted Lamaist Buddhism, created new hybrid monasteries, thereby establishing the first firm Chinese connection to Tibet. In Japan, meanwhile, a shift in power from the emperor to the aristocracy was accompanied by the growth of a new form of Buddhism, popular in contemporary Song China, known as Pure Land Buddhism.

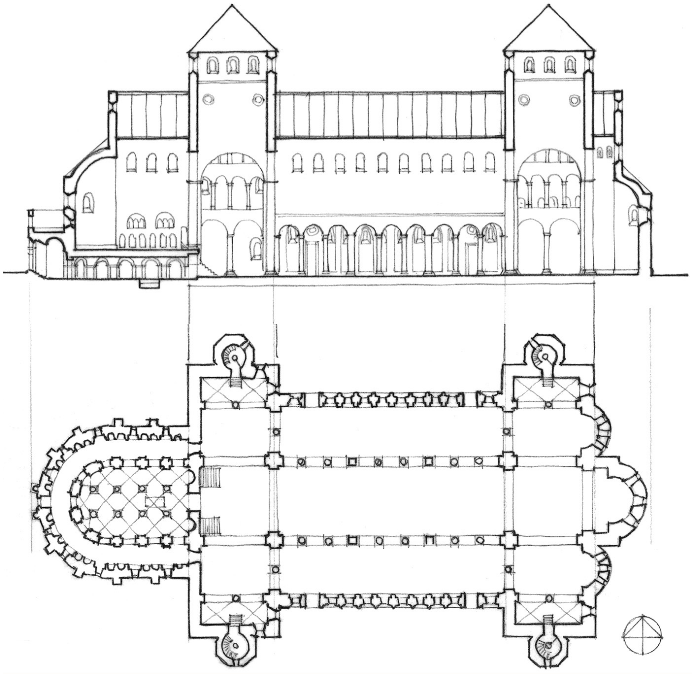
In the Islamic world, we begin to see the political and religious patterns that were to determine the power gambits of these regions for centuries to come. Islam had divided itself into different political entities with the differences between Sunni and Shi'ite becoming irreversible. From west to east, we find the Berber Almoravids, who took control of Spain and linked it with their home base around Marrakech; the Shi'ite Fatimids, who controlled Algeria and Egypt; the Sunni Seljuk Turkomans, who had subdued Persia and whose leader became the new caliph in 1055; and the largely Sunni Ghaznavid Empire, stretching from Afghanistan to northern India. All were great mosque and palace builders. The Seljuks remain the most impressive, however, as they imposed a particularly coherent political, religious, and economic architecture on their territory. The Silk Route, though diminished, continued to flourish with the Armenian capital, Ani, becoming a significant stop. Another important city was Cairo, which had, under the Fatimid, been provided with several new mosques and palaces.



Section of the Shrine of Imam Dur, Samarra, Iraq, . 1085 CE



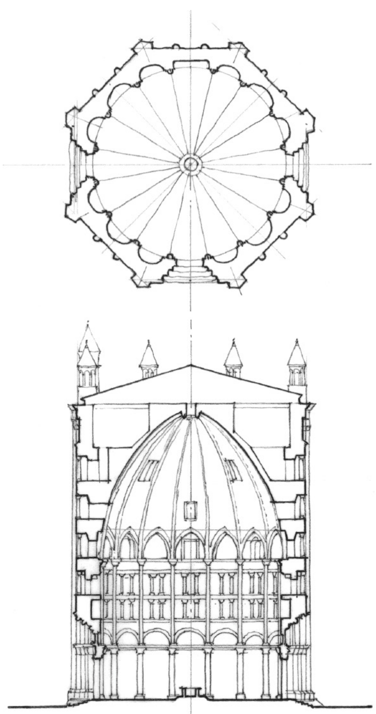
Plan of the qubba, Al-Barubiyyin, Marrakech, Morocco, 1117 CE >



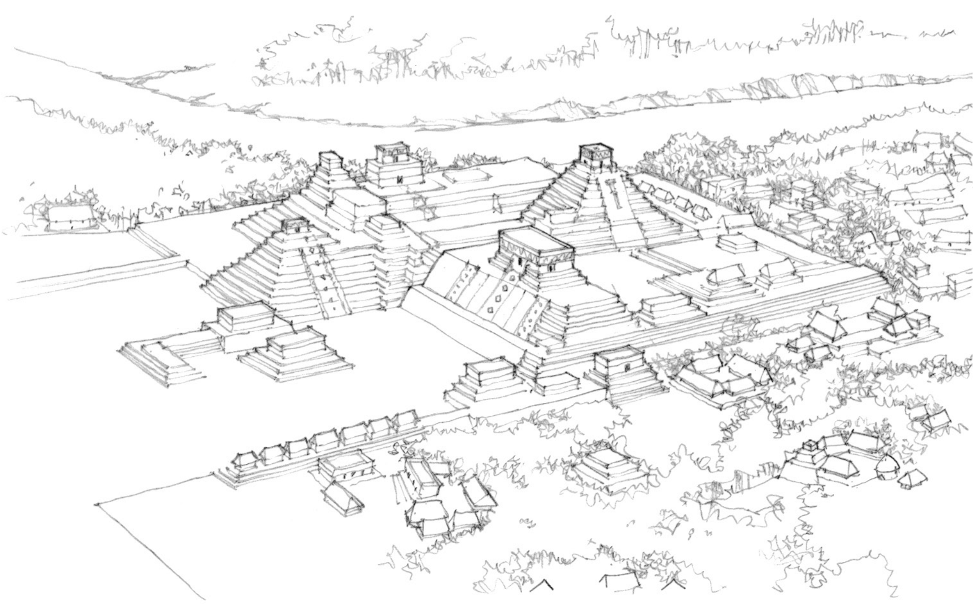
St. Michael in Hildesheim, Germany, 1001–1033 CE

In Europe, the struggle for dominance was led by the Ottonian kings in Germany and the Normans in England. Both used a combination of religious and military institutions to stamp their authority on the land. The Ottonians combined monasteries with local market towns, whereas the Normans reorganized the entire legal and religious landscape of England. The visible result, in architectural terms, was the appearance of cathedrals, castles, and monasteries, which tended to blend continental and Islamic features, partially creating the base of what would later be known as Gothic architecture. Also developing was a complex monastic network with the Cluniacs, in particular, controlling monasteries across France, Italy, Germany, and Spain, creating a rapid development in architectural language. At the same time, another type of religious geography emerged as a result of the developing pilgrimage routes that linked far distant destinations and spread architectural knowledge from place to place. Italy was slowly developing its own architectural expressions, including the baptistery, which was located at the center of the town next to the duomo or cathedral, which was paid for with city funds rather than—as was common in France and England—through royal patronage and taxes.

In the Yucatan Peninsula, the Maya were at their height. In the valley of Oaxaca the Zapotecs continued to build new cities, and in the north the Toltecs were in the process of building a powerful new dynasty destined to define the form and shape of the cultures that the Spanish conquistadors encountered 500 years later.



Baptistery at Parma, Italy, 1196–1270 CE

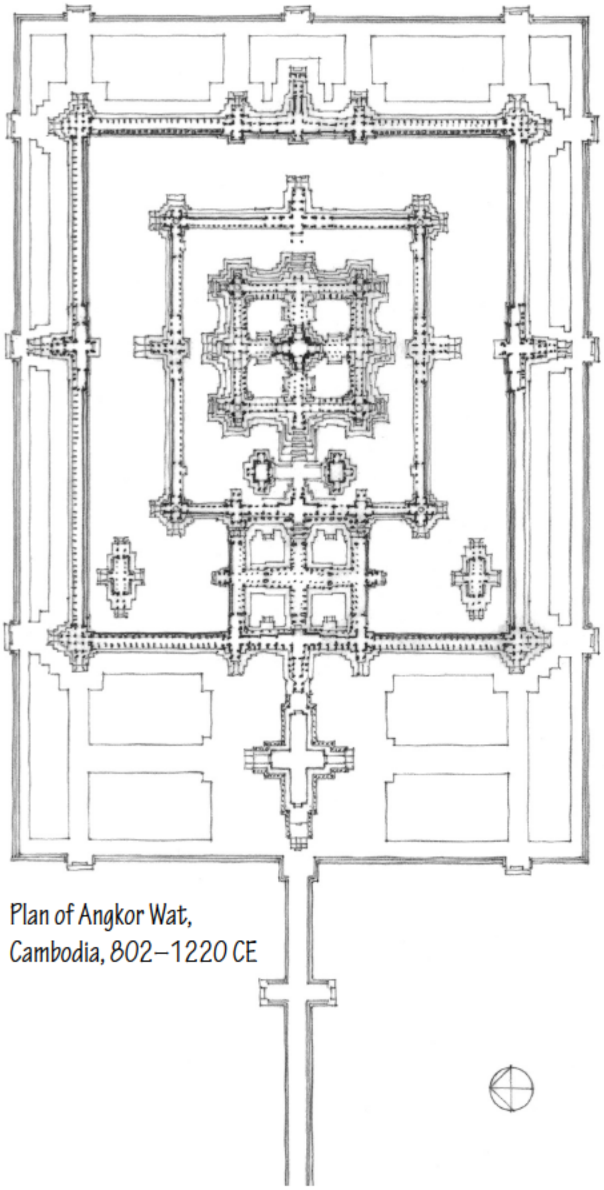


Aerial view of the Mayan city of Copán, from 400 BCE

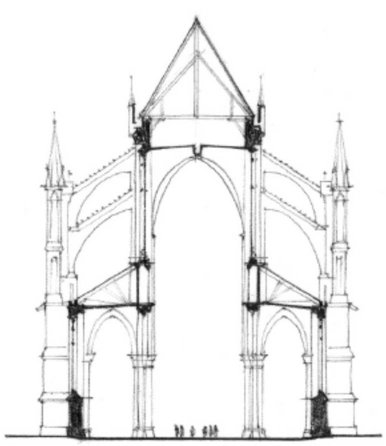
1200 CE

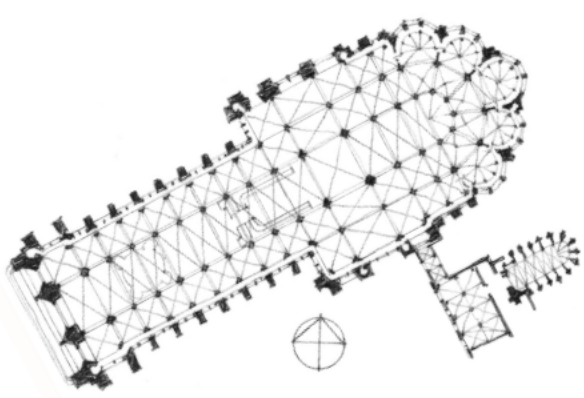
The history of religions is never static, and this is especially true during this period. In Japan, Buddhism developed into a variant known as Pure Land Buddhism, which is based on the concept of visualizations as the path to liberation. The Itsukushima Shrine in Japan brought out the delicate balance between Pure Land Buddhism's attempt to achieve a balance between outer landscape and inner meditation. In China, Mahayana Buddhism continued to take the form of large state-sponsored monasteries with the pagoda (ta) serving as a vertical representation of the many levels of enlightenment. In Pagan, in modern Nyanmar, Buddhism came to be associated with didactic panels placed inside the temple superstructures. Buildings that were once meant to be solid now had dramatic internal illumination. In Cambodia, the Khmer rulers shifted from Shiavite Buddhists to Vishnaites, because the latter better served their developing ideology of royal divinity. Scale was no issue. Angkor Wat remains one of the largest religious buildings in the world. In South Asia, Hinduism continued its transformation into a religion with a multifaceted pantheon. The Orissan kings emphasized the sun god in a temple that had at its symbolic center an enormous stone chariot. The Hoysalas developed temples with a star-shaped plan to accommodate multiple deities.

In the Christian world, the situation was equally diverse and fluid. One finds the almost simultaneous development of large urban cathedrals that required the coordination of the powers of the Roman Church with those of the state (Gloucester Cathedral in Norman England), pilgrimage churches with their emphasis on the Virgin Mary (Notre Dame of Reims in France), and churches belonging to a new type of religious order, namely the mendicants who renounced the wealth and ostentation of the great cathedrals, preferring instead simple and modest buildings (e.g., the Dominican Church of Toulouse). In Italy, the urban cathedrals and mendicant churches formed composite, though somewhat contradictory, liturgical spaces. The Ethiopians, who maintained the great tradition of rock cutting, created an entire liturgical landscape based on distant Jerusalem.



Plan of Angkor Wat, Cambodia, 802–1220 CE

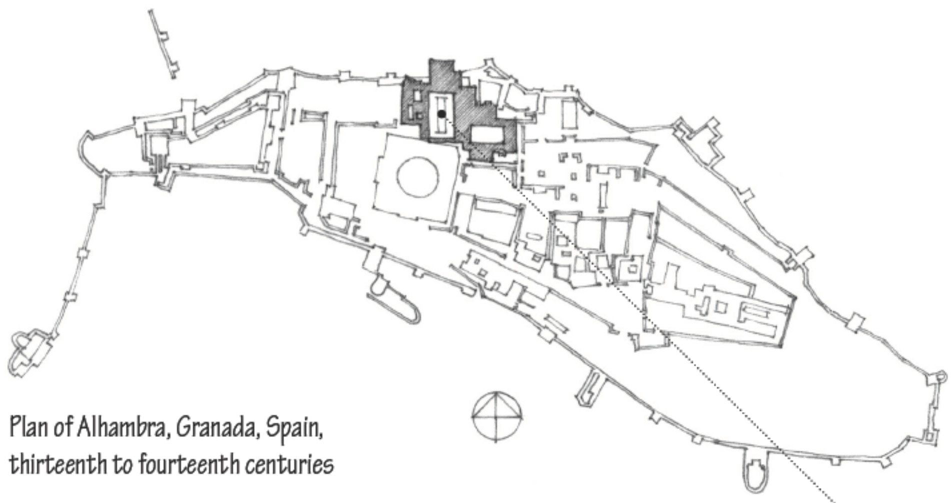




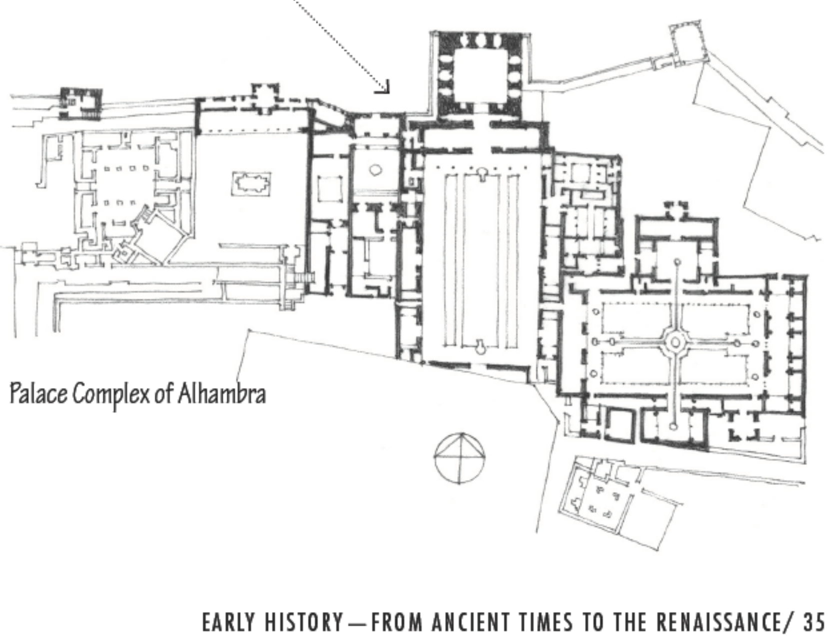
Section and plan of Notre Dame of Reims, France, 1211–1290 CE

Section through rock-cut churches of Lalibela, Ethiopia, thirteenth century CE

If one follows the dots on the map, it becomes clear that there is a major gap in the area from Central Asia to the Near East, in largely Islamic lands, where architecture was in a virtual standstill from 1220 on to about 1330 because of the Mongolian disruptions. Mongolian armies invaded south into China and Burma and westward into Russia and Anatolia, altering the economic and political landscape everywhere they went. The Song in China, the Seljuks in Anatolia, the Delhi Sultanate in north India, and the Novgorod Empire in Russia all came to a rather sudden end. The only Islamic region to prosper, well out of the range of the Mongolians, was Spain and North Africa, where one finds in Fez and Granada new mosques and palaces. The most spectacular of the palaces was the Alhambra.



Plan of Alhambra, Granada, Spain, thirteenth to fourteenth centuries

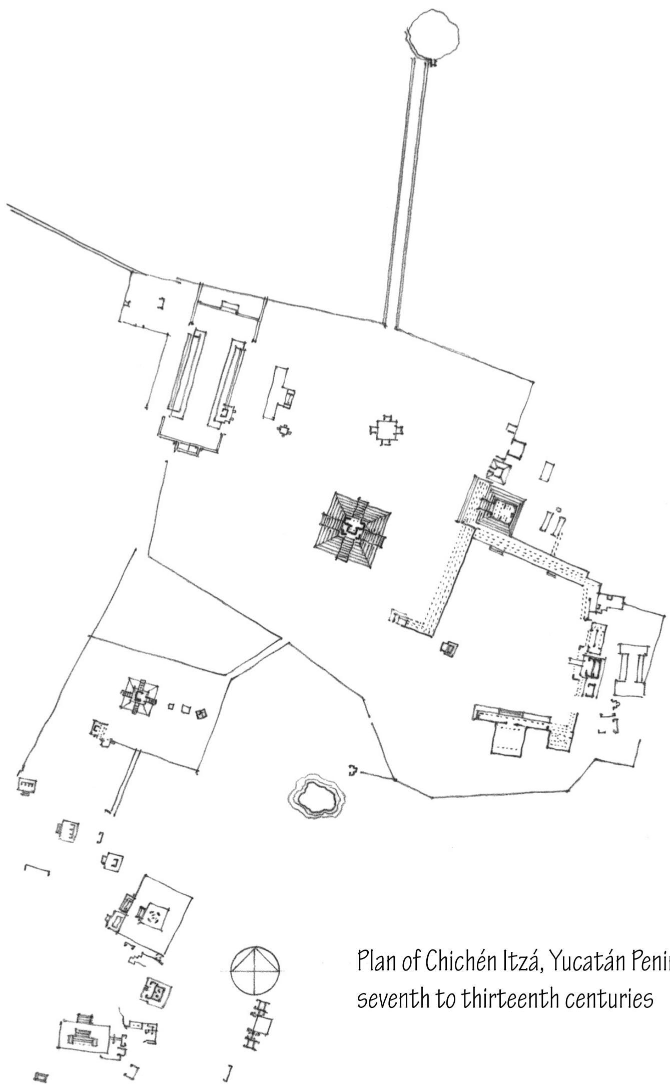


Palace Complex of Alhambra

Once the destructive fury was over, the Mongolians were quick to adapt to local customs and ways, becoming Buddhist, Confucian, or Islamic, both Sunni and Shi'ite, depending on where they were. In China, they founded the Yuan Dynasty. It is also apparent that by eliminating regional rivalries, at least for a while, the Mongolians lowered the risks of trade across the great distances of the Eurasian continent. This enabled the quickening of the Eurasian economy that reached its zenith in the fifteenth and sixteenth centuries. One of the consequences of the Mongolian thirteenth-century domination of the Eurasian north was the rapid development of a sea-based southern economy that stretched from Africa, India, and Indonesia to China. Southeast Asia, in fact, now became an economic zone all its own with Pagan, the Khmer in Cambodia, and the Srivijayan Empire in Malaysia and Sumatra controlling trade between India and China, and they themselves becoming major rice producers. The coastal ports extending from southern China to eastern Africa were now all part of a single trade network.

This was the period of an amazing cast of architectural patrons: Emperor Huizong (1100–1125) in China; Prime Minister Taira no Kiyomori (1118–1181) in Japan; Suryavarman II (1113–1145) in Cambodia; King Kyanzittha (1084–1113) of Burma; Qutb-ud-Din Aibak (1150–1210) in northern India; King Narasimhadeva (1238–1264) of Orissa; King Lalibela (1185–1225) in Ethiopia; Mohammed I (1238–1273) of Islamic Spain; and Frederick II (1194–1250) of the Holy Roman Empire.

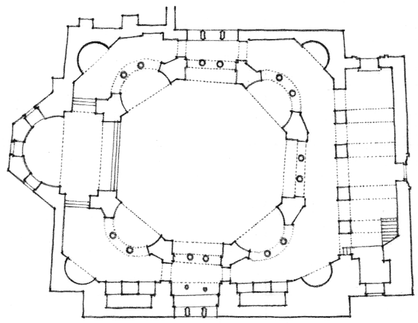
In Central America, the Toltecs, claiming descent from Teotihuacán, established a militaristic culture that was to define the region's civilizations right up to the Spanish conquest. In the Yucatan, Chichén Itzá emerged as the primary city-state, the final moment of Mayan development before their final collapse around 1250.



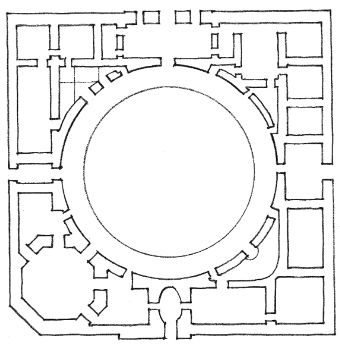
Plan of Chichén Itzá, Yucatán Peninsula, seventh to thirteenth centuries

3 A Concise History:

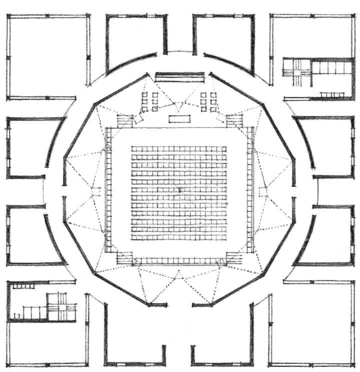
Architecture from the Renaissance to the Contemporary



S.S. Sergius and Bacchus, Istanbul, 525–530 CE



Palace of Charles V, Granada, Spain, 1527–1568



First Unitarian Church, Rochester, New York, Louis Kahn, 1959

Influences of the Past

Often, architecture is seen as a discipline that thrives on innovation, sometimes even novelty. However, architecture is largely influenced by that which came before it. The discipline, as a whole, advances through an accumulation of thought rather than sudden generation of entirely new ideas. Any modern application of a design principle will likely have a historic precedent from which it can be traced. It is for this reason that historic study is not only valuable, but also necessary for architecture to be successful. This chapter briefly discusses the evolution of architectural thinking from the Renaissance to the contemporary. It provides a timeline of architectural development relative to corresponding events. From this chapter, you will be able to better understand the forces that influence architectural evolution from the Renaissance to Postmodernism.

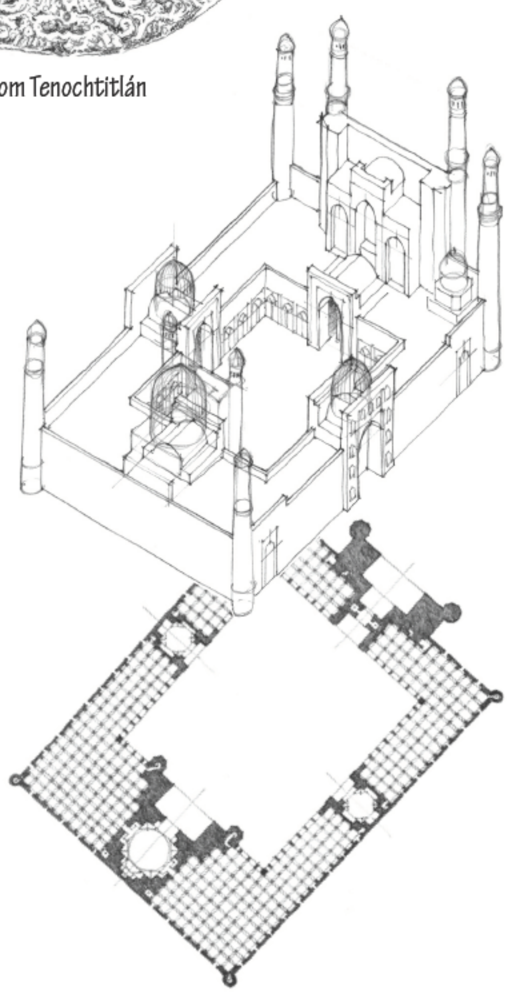
Pictorial view of Templo Mayor,
Tenochtitlán, Mexico City, ca. 1325–1521

Calendar stone from Tenochtitlán

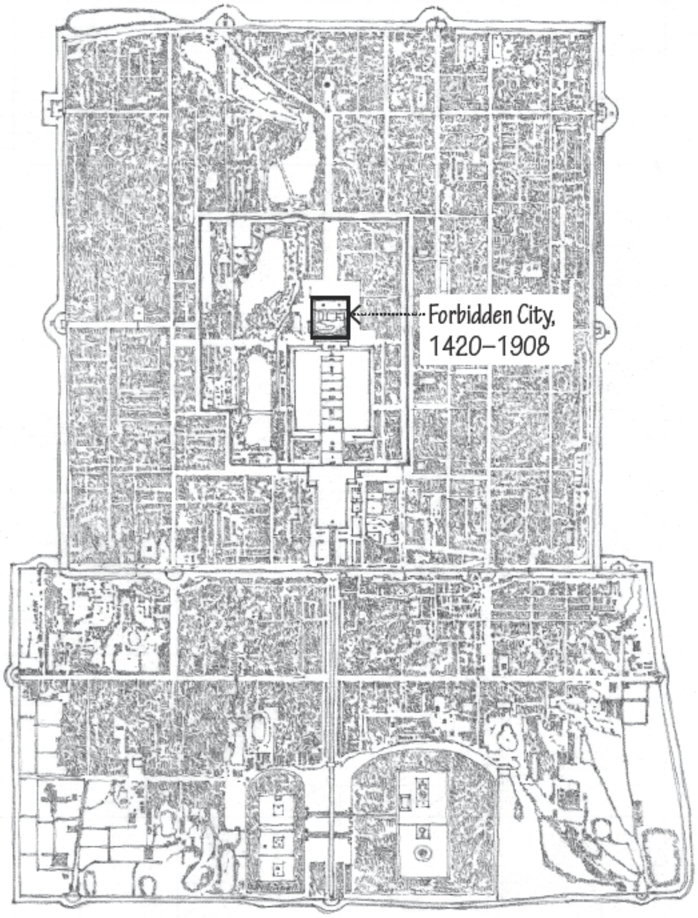
1400 CE

In 1250, a century after the fall of the Toltecs, Chichén Itzá was abandoned. A migrant group from the north, known as the Mexica, settled into the central valleys of Mexico, establishing new cities. After two centuries of conflict, the city of Tenochca concluded a military alliance with the Acolhua of Texcoco and the Tepanecs of Tlacopan, forming a powerful bloc linking most of central Mexico. Their capital was Tenochtitlán, the site of contemporary Mexico City. To the south, the Chimu kingdom controlled the territories of coastal South America in the thirteenth and fourteenth centuries. Here, they exploited the arid climate to build one of the world's largest cities ever made from adobe, an ancient type of sun dried brick made of clay, sand, and water with some straw mixed in. In the middle of the fifteenth century the Chimu were displaced by upstart rulers from the highlands of Peru, the Incas, with their capital in Cuzco. In their short life before they fell to the Spanish, the Incas dominated the trade routes of coastal South America, constructed long rope bridges, and built roads and cities with some of the most intricate and precise random rubble masonry ever seen in history.

The year 1400 marks more or less the end of the great conquests from the Russian steppes. The arrows on the maps showing the Gauls, the Huns, the Turks, the Mongolians, and other tribes from the steppes are no longer there; the Eurasian world for the first time in 1000 years was not beset by migratory invaders. The impact of the invaders had not been all negative; within a short time period, the respective tribes had adapted and started to make their own type of contribution whether that be the Liao tribes in China, who adopted Chinese ways, or the Huns in Eastern Europe, who converted to Christianity, so that within a brief span of time, novel civilizational and aesthetical imperatives were under way. Typical for this period was the emergence of a new wave of global urbanism. In fact, many of the cities that today are at the very center of much of preservation efforts date from this period.



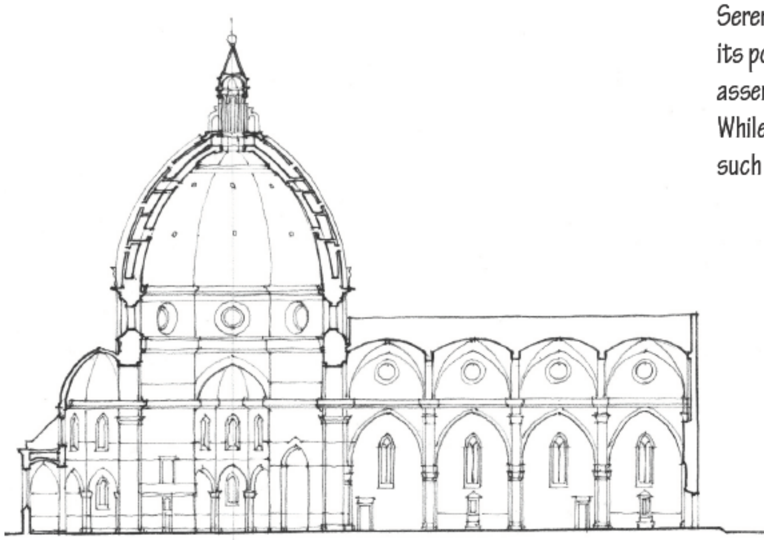
Bibi Khanum Friday Mosque, Samarkand,
Uzbekistan, 1339–1404



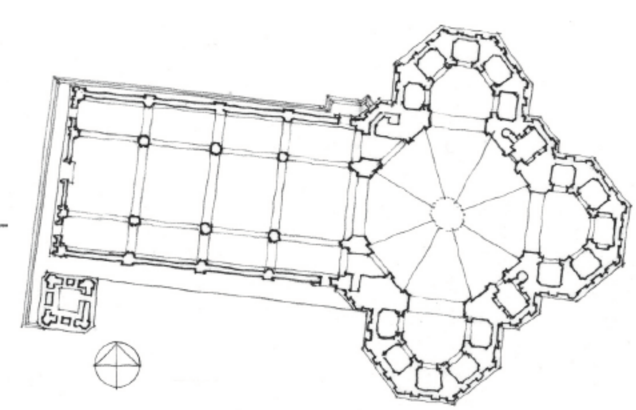
Plan of Beijing, China

In Korea, Seoul was transformed into a great and impressive capital. In China, Beijing's Forbidden City was built. Islam, of course, was also rebounding and expressing its wealth in mosques and schools and mausoleums from Egypt to northern India. Samarkand, the capital of Timurid, was expanded and was perhaps the leading economic city of the world. Close by was the bustling metropolis of Bukhara, the Shaybanid capital. Further to the east, the Mamluks were making considerable improvements to the city of Cairo. More or less absent in this is Southeast Asia. The decline of the Khmer brought the entire region into decline, with the exception of the Thai, who at their new capital, Ayutthaya, were able to expand into the vacuum. It is a great irony that, with the increased trade in the fourteenth century, the Black Plague made its inroads, killing hundreds of thousands worldwide and placing a damper on European economic progress. Nonetheless, by the middle of the fifteenth century enough of a recovery had been made so that the true impact of the invasion period could be seen.

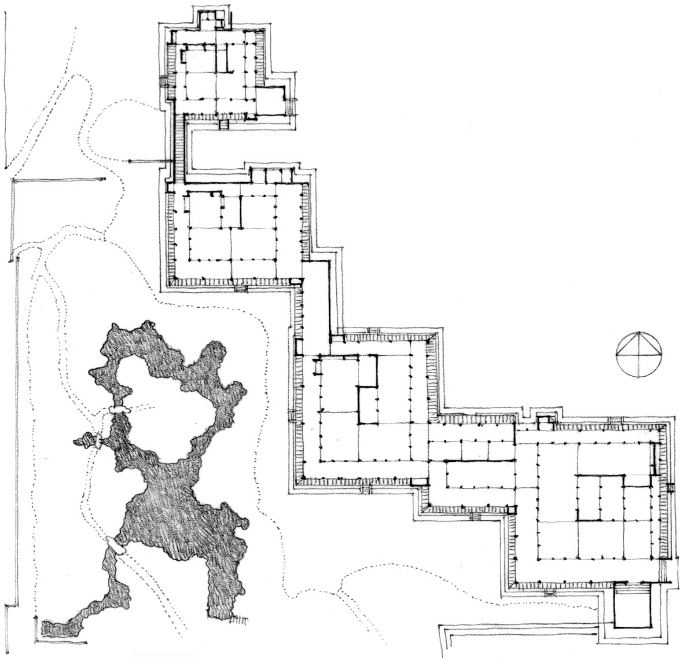
The Italian Renaissance can only be understood if one considers the new position of Italy in the global economy. With the restoration of trade links to China, Italy, with its energetic mercantile city-states, was excellently positioned to link up with the great trade routes ending in the Levant. Although far from unified, its rival city states invested their newly acquired resources in art and learning, so that, as a totality, it became a dominant cultural force in Europe. The Venetian Republic with its famed maritime fleet and trading posts throughout the eastern Mediterranean, some acquired during the crusader period for which the Serenissima had supplied transport, minted its own coins, and secured its position as the world's leading gold market. Florence also began to assert itself, with the Medici becoming the leading bankers in Europe. While much building activity was going on in Florence and Venice, cities such as London, Aachen, and Paris were falling into disrepair.



Cathedral of Florence, begun 1294

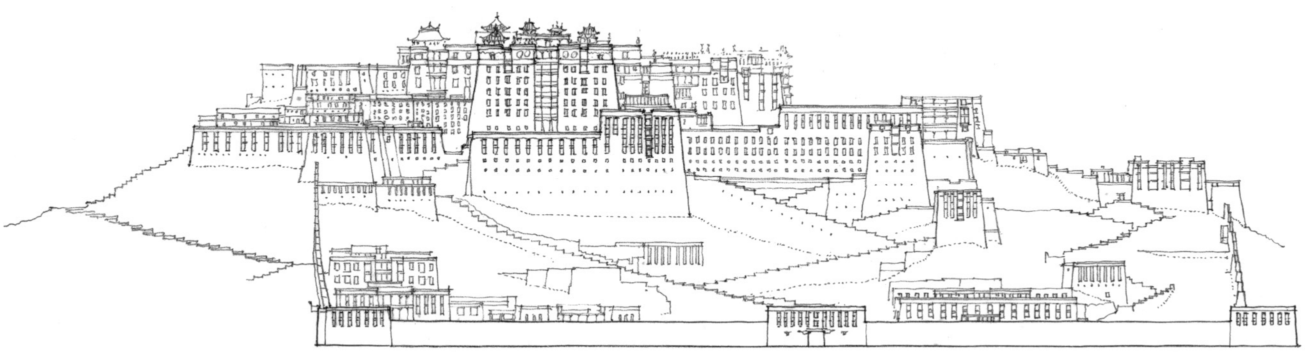


1600 CE: Architecture of the Eurasian Power Bloc



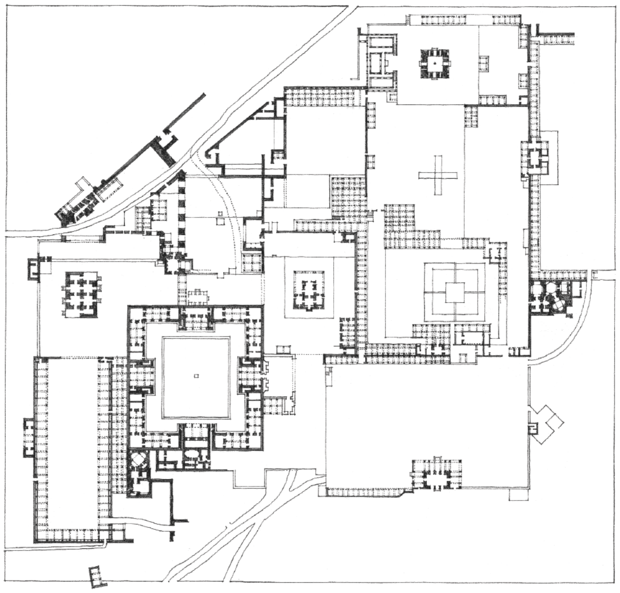
Ninomaru Palace, Nijo Castle, Kyoto, Japan, 1601–1603

In the seventeenth century, the Eurasian world from Japan to Western Europe was a contiguous economic power bloc, because of established cross-country and coastal trade. From one end to the other, wealth and ideas traveled in the baggage or minds of traders, migrants, and armies. This was the Old World order that was now increasingly undermined by the newly arising more efficient ocean trade. Imagine a traveler in 1652 starting a trip through Europe and Asia to study the latest developments in the field of architecture. Starting in Japan, he is led through the Ninomaru Palace in Nijo Castle, located in the heart of Kyoto, the capital of Japan. He then visits the austere Katsura Imperial Villa and is introduced by his hosts to the newly developed intricacies of the Zen tea ceremony. Crossing into Korea, he visits the Gyeongbok Palace in Seoul (begun in 1394), led there by a Mongolian serving in the Manchu empire, which had reduced Korea to a vassal state. Traveling with a Mongolian commander into the heart of Manchuria through Mukden, its capital, he visits the then still relatively recent Forbidden City that was just then being refurbished by the new Manchu rulers who had just taken over Beijing in the heart of which it is located. The times are just stable enough to travel to the nearby Ming tombs. On the way, he discusses with his guides the pros and cons of the Chinese international seafaring voyages and whether or not they should be continued.

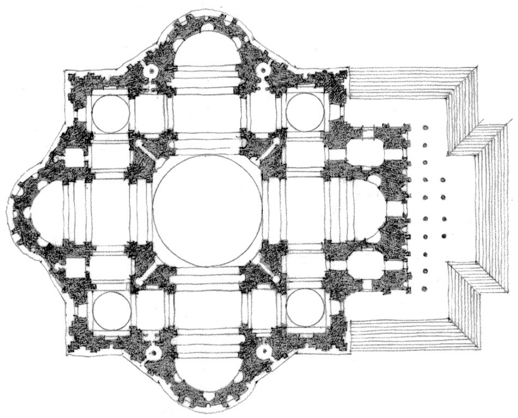


Potala Palace, Lhasa, Tibet, 1649–1694

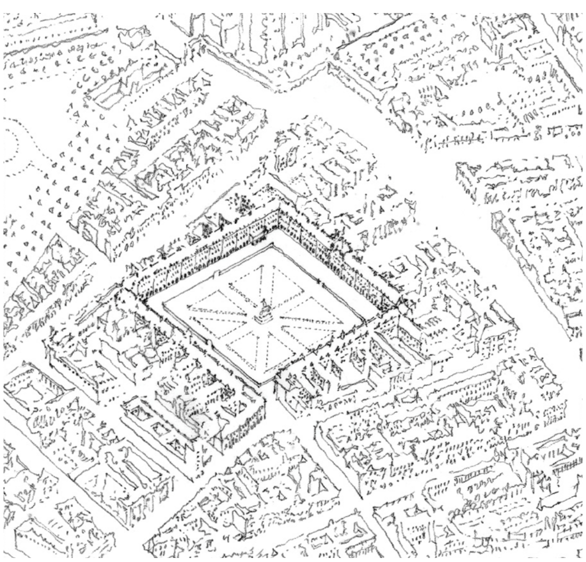
He then works his way southward into the highland plateau of Tibet to visit the dramatic Potala Palace built on a steep rocky crest for the fifth Dalai Lama, whose supporters had carved out an important political territory in the Lhasa Valley in the Himalayas. Descending to the fertile plains of the Ganges, he now travels through areas controlled by one of the Islamized descendants of the Mongols, Akbar the Great. He makes his way past Man Mandir, one of the grand sixteenth-century palaces of the city of Gwalior in central India, and on to Delhi and its expansive palaces. He inspects the great planned city, Fatehpur Sikri, capital of the Mughal Empire from 1571 to 1585, laid out by Akbar himself, and then heads up the Yamuna River to see the just-completed Illumined Tomb, later to be known as the Taj Mahal. Here, he hears of new Portuguese settlers living in a small coastal town called Goa.



Palace precinct, Fatehpur Sikri, India, 1569–1574



Michaelangelo's plan for St. Peter's Basilica in Rome, 1547

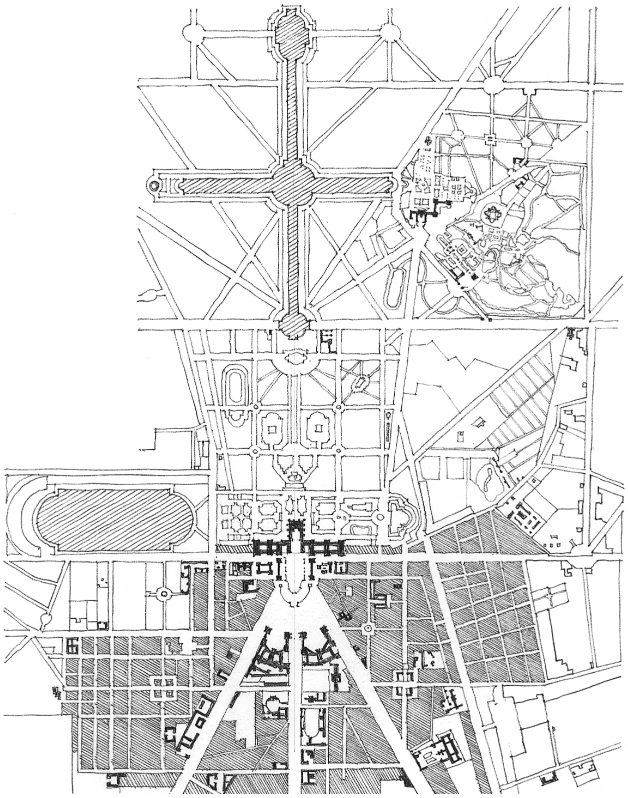


Place Royale, Paris, begun 1605

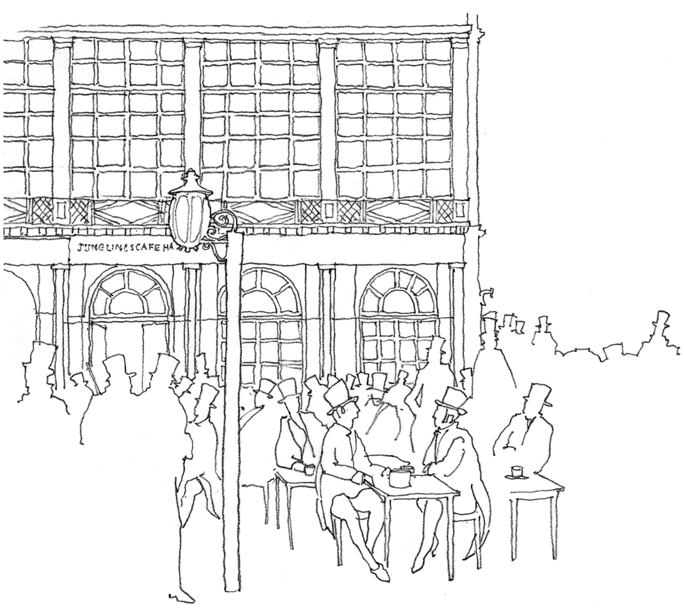
He then heads for Kandahar and crosses into Persian territory, following the trade routes to Isfahan, where he sees the vast urban extension of Isfahan with its enormous city square, sumptuous mosques, and broad royal gardens. There, he meets traders from as far away as England. From Isfahan, he crosses mountains and deserts into areas newly controlled by the Ottomans and, following the old Seljuk caravan routes, makes his way to Antioch on the Mediterranean where he boards a ship to Istanbul. This city, taken by the Ottomans in 1453, was in the process of being rebuilt by its new lords. He admires the great Hagia Sophia, but his guide points out to him the superiority of the recently built mosques by Mimar Sinan (1489–1588), the great architect and engineer.

From Istanbul, he departs on a merchant ship for the somewhat faded port of Venice and is told there of economic hardships and of Dutch competition while being led to see the churches of St. Giorgio Maggiore by Andrea Palladio. He then follows a group of pilgrims to Rome, a city awash in Spanish money. The dome of St. Peter's basilica, based on designs by Michelangelo and one of the most demanding and exciting building projects in all of Europe, was just being finished. In front of the church, he sees a vast area that had just been cleared to make way for Gian Lorenzo Bernini's colonnaded Piazza of St. Peter's. He takes the time to visit the recently finished building by Francesco Borromini, Sant'Ivo alla Sapienza, and to discuss with its priests the efforts to strengthen the Counter-Reformation.

From the Roman port of Ostia, he travels by boat to Marseilles and then northward, working his way through France. He admires the new wealth of the aristocracy and sees some of the great chateaux such as the Chateau de Chambord of Francis I on the Loire, the double helical staircase of which may have been designed by Leonardo da Vinci who, invited by Francis I, had spent his retirement years near the king. Our traveler also visited the Place Royale in Paris, stopping along the way, no doubt, to admire the great cathedrals. But to see the energy of the Europeans in action, he goes to Amsterdam, a world metropolis with neither grand palaces nor dominating churches but with a bustling port, testimony to Dutch mercantile prowess. He visits the new city hall and bank with the world maps inlaid in marble on the floor. He takes time to visit his first Protestant churches, plain and austere, and is told of terrible religious wars. In crossing the English Channel, he visits the newly built Banqueting House (1619–1622) one of the first buildings in England to be designed in the modern Italianate manner, a structure representing an ambitious but—from the point of view of the Chinese, Moghuls, Ottomans, and Dutch— still relatively marginal power, namely England whose major export commodity was still wool, and whose foreign policy was still driven more by piracy than by politics.



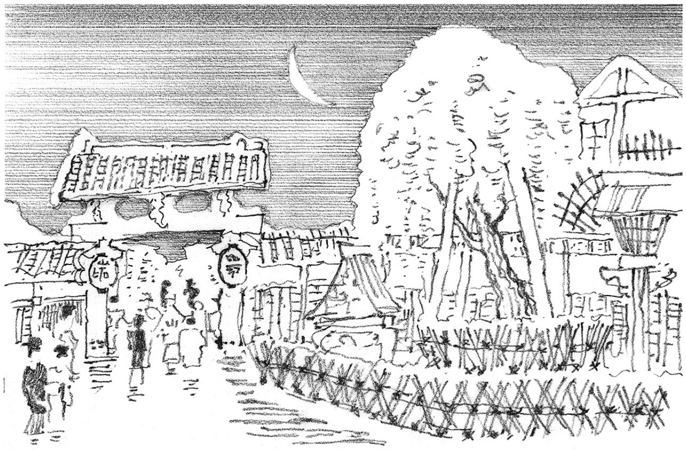
Plan of Versailles, France, 1661–1778



Kaffeehaus Jüngling, Vienna, ca. 1838

1700 CE

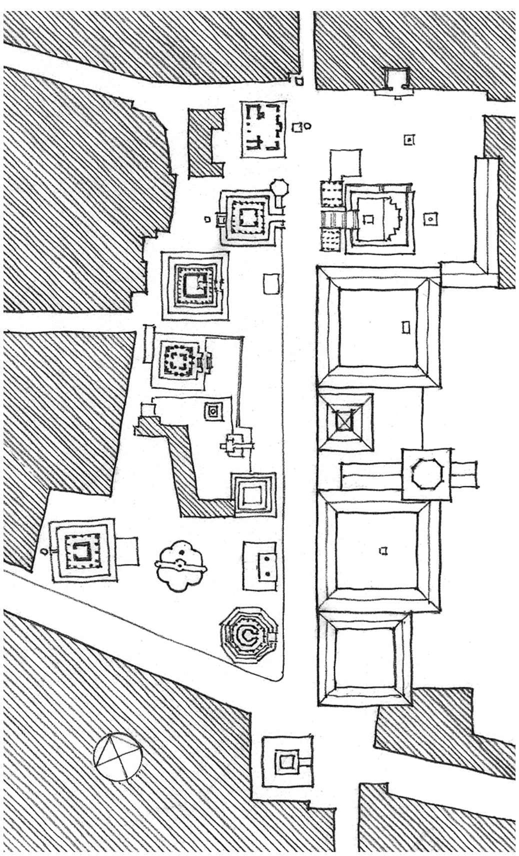
By the early eighteenth century, cities like Samarkand, Bukhara, and Aleppo, which had once been at the heart of the Eurasian trade, had become increasingly marginal to the new world economy of the maritime ports that were set up by the European powers. One need only think of such major new metropolises as Macau, Hong Kong, Singapore, Bombay, Calcutta, Madras, Cape Town, Senegal (originally St. Louis), Rio de Janeiro, Buenos Aires, Boston, New York, and Quebec City to remind ourselves of the global scope of this phenomenon. At the foundation of the system was the fort and the plantation. Local populations were transformed into work forces, and when these were in short supply, enslaved and indentured laborers from Africa and Asia were brought in on ships. In Europe, it was the French who first translated colonial power and wealth into large-scale architectural projects, none grander than Versailles (1668). Aristocratic privilege and high-bourgeois mercantilism resulted in large residences reflecting the social pretensions of their owners and the new economic conditions. New building types, such as bourgeois apartments (or hotels), coffee houses, parks, and theaters, sprang up to nourish the new culture. It was also a time of unease. Religious persecutions were at their height and tensions between the European powers over control of the global economy resulted in a series of costly wars. The Dutch War (1672–1678) concluded in favor of the French, but later the War of Spanish Succession (1701–1714) created an important power shift in the direction of Austria and England, paving the way for places like Schönbrunn Palace (begun 1695) and Blenheim Palace (1705–1722). Russia, too, was a rising power, redefining itself in the European model, both culturally and architecturally, with its impressively scaled new capital of St. Petersburg, founded in 1703. Throughout Europe, the Baroque style, as it came to be known, was dominant with thousands of churches built or refurbished in that manner. Huge palaces were also built first in France and then in Austria, Italy, and Germany, with long allées and gardens stretching far into the landscape. The increasing centralization of governments led to the creation of new state institutions, such as hospitals and asylums.



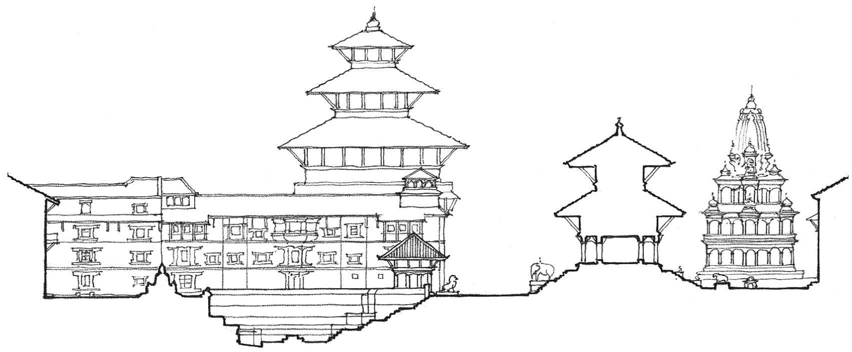
Facsimile of Tobei Kamei's block print of the Shimabara geisha district in Kyoto

China and Japan were, however, still economically and politically balanced against the colonizing West. The Qing annexed parts of central Asia and Tibet to make the largest Chinese empire in history. To accommodate China's diverse populations, the Qianlong emperor developed a pan-Asian conception of empire, building dozens of new palaces and gardens and reestablishing the Yuan-era link with Tibetan Buddhism. Since Chinese currency was based on the silver standard, European traders, anxious for Chinese goods, were pouring silver into the empire. In Japan, the Tokugawa shogunates were in the midst of redefining the culture, creating a world that followed a strict code of behavior that was, in many respects, astonishingly modern, as the rising middle class sought ways to articulate institutions suitable to its needs despite the restrictions placed on it by the shoguns.

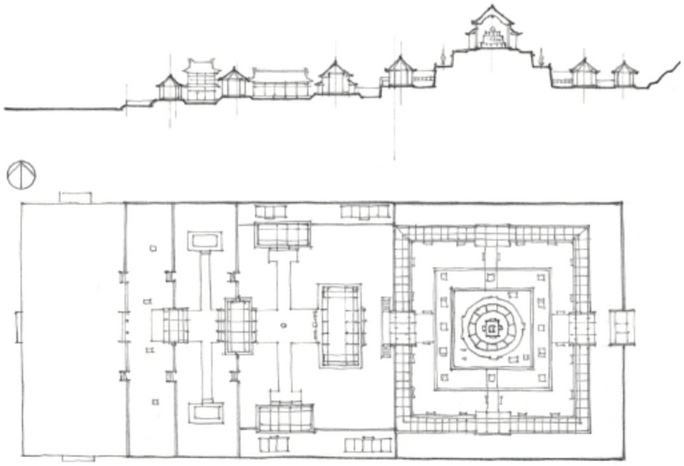
In India, in the brief period of time as the Moghul Empire weakened and before the full colonization of India, local governors took the opportunity to proclaim independence. Shuja-ud-Daula in northern India, the Nawab of Oudh in Bengal, the Sikhs in Punjab, the Rajputs in Rajasthan, and the Marathas in the Deccan wrestled among each other for power at the same time as European colonizers began to build on their coastal footholds and start to acquire hinterlands. As a result, though this was a turbulent period in India, it was also a time of tremendous exploration from a cultural and architectural point of view. The Sikhs, a reformist movement, took root in northwestern India and established a formidable kingdom. Darbar Sahib (Golden Temple) in Amritsar was their most important shrine. The Mallas of Nepal, meanwhile, enjoyed relative immunity from these global events next door, but their royal square in Patan embodied its own global history. In contrast to the energy in Europe, India, and East Asia, building activity in West and Central Asia slowed down. This was so pronounced that most books dealing with Islamic architecture end around 1750. The result was that East and West, both strong and viable, split around an increasingly economically marginalized center.



Durbar Square, Patan, Nepal, rebuilt seventeenth century



East-west section of Durbar Square, looking south



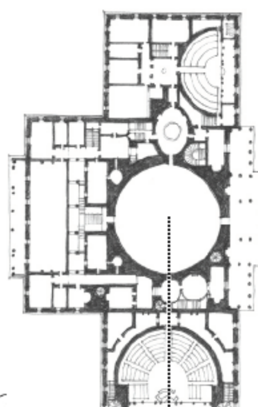
Plan and section of the Pulesi, Chengde, China, 1767

1800 CE

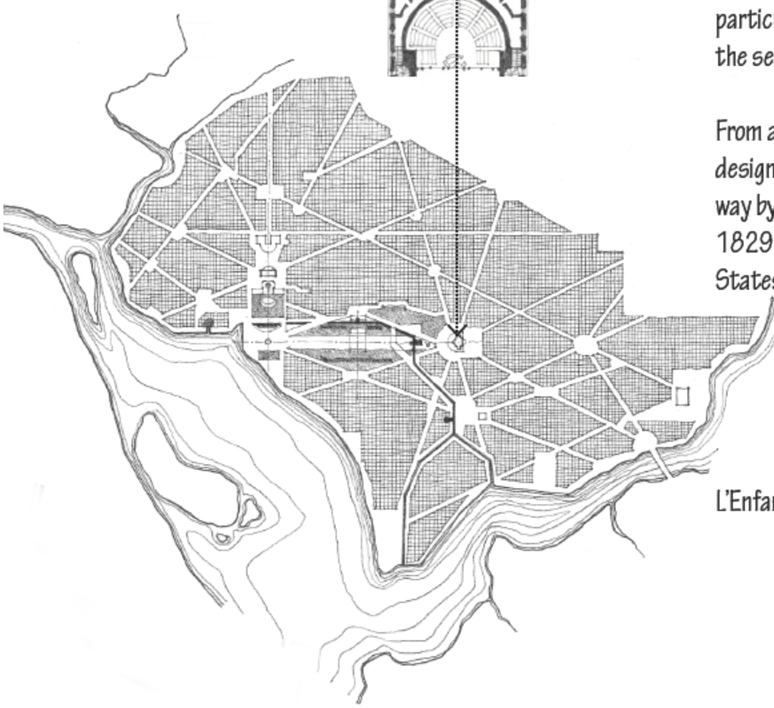
Even as Europe grew from strength to strength, the largest world power in the year 1800 was China. It may not have manifested itself as such, since it had no colonies. It extended its borders the old-fashioned way, conquering Tibet, Turkestan, and Mongolia. In size, population, production, and raw wealth, it had no equal. Its bold-thinking emperor, Qianlong, aimed to create a pan-Asian empire, unified around the Indic origin ideal of cakravartin. Because Chinese architecture never underwent radical changes in its visual and formal vocabulary, there has been a tendency to see it as tradition bound, but that would be an all-too-simple reduction. Qianlong's purposeful use of imitation in constructing his new capital city, Chengde, was driven by the ideological innovation of constructing a vision of China as the center of a pan-Asian world. The Chinese world, however, went into rapid decline once the British forced the Chinese to accept ever more opium, against the Chinese imperial desires, in "exchange" for tea.

Europe was also undergoing a foundational revision as a consequence of the Enlightenment, which revised ideas about nature, law, and government. Napoleon and his armies forced change not only in France but also in Italy, Austria, and Germany. The stranglehold of the aristocracy had been broken and its arbitrary aspects revealed. New building types relating to government and bureaucracy emerged. In that respect, one can compare the Somerset House in London (1776–1801), the U.S. Capitol (1792), the Four Courts in Dublin (1786–1802), the Virginia State Capitol (1785), the Government House in Calcutta, and the new Houses of Parliament in London (1840–1860). The architecture of administration brought with it other forms of architecture, for example, of control, such as the panoptic prison. In the United States, the Enlightenment was, however, expressed with particularly utopian fervor, spurred on by the American Revolution and the sense that America was the land of untold opportunities.

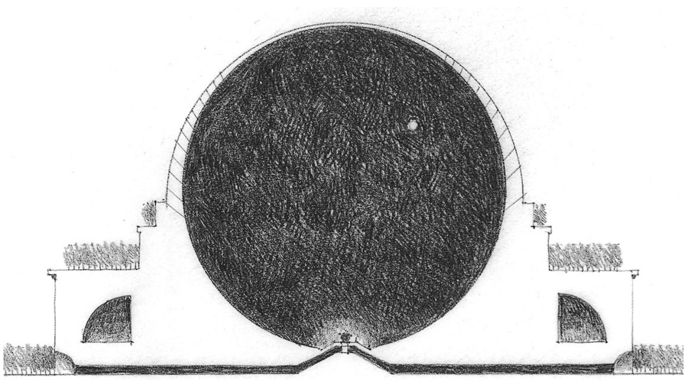
From an urban point of view, some of the most important cities being designed were Chengde in China and Washington, D.C., both well under way by 1800. The liberation of Greece from Ottoman occupation in 1829 spawned a vigorous neo-Greek movement not only in the United States, but also in Germany and Scotland, and in British India.



Plan for the U.S. Capitol, Washington, D.C., William Thornton, 1793, modified by Henry Latrobe in 1817



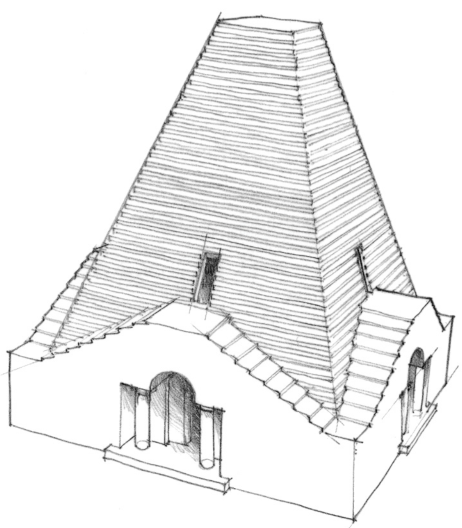
L'Enfant's plan for Washington, D.C., 1792



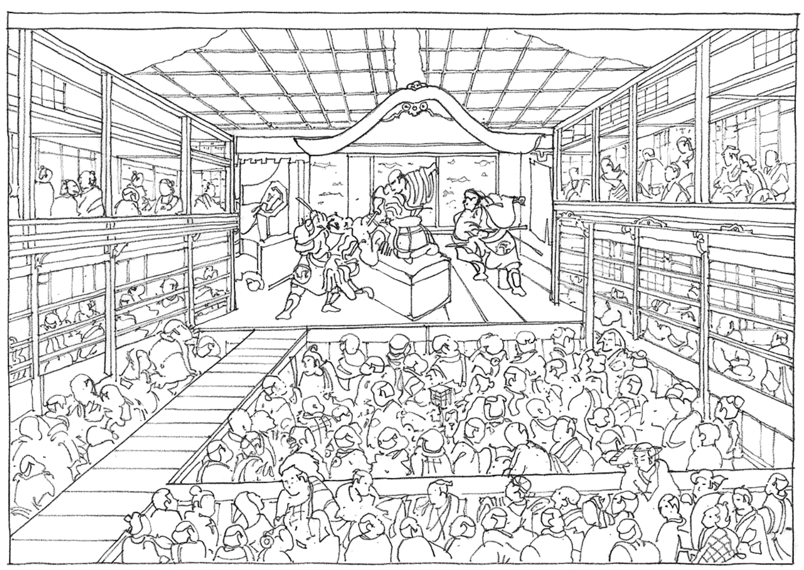
Cenotaph for Sir Isaac Newton, Étienne-Louis Boullée (1728–1799)

The utopianism of the European Enlightenment was generally tempered, if not co-opted outright, by the lingering traditions of aristocratic privilege, producing an architecture generally known as neoclassical, the history of which took many turns and in some cases retreated toward a more conservative romanticism, especially in England. Nonetheless, traces of a more vigorous and austere neoclassicism, such as that pursued by the French architects Claude Nicholas Ledoux and Étienne-Louis Boullée, are to be found throughout Europe from 1800 onward. The reaction against neoclassicism and the spread of romanticism, developing into national romanticism after the Napoleonic Wars, became increasingly important as the century progressed.

Apart from China, Europe, and the European-controlled colonies, there were two areas that continued to develop architecturally but in very different ways—Japan and Thailand. Japan, like China, had closed itself off from European influence, but it maintained a strong architectural tradition, developing a "modern" architecture of the middle class, as in Kabuki theater. Thailand, which was never colonized, was, by way of contrast, more than willing to open itself up to Western influence, unifying borrowed elements into regionally developed forms of practice. In that sense, the story of nineteenth-century urbanism has to include not only such new cities such as Washington, D.C., and the redesigning of such older cities as Berlin, London, Paris, Dublin, and Athens but also Bangkok, the newly founded capital of Thailand. Thailand gives us a glimpse of what modern "Eastern" architecture looks like that was neither colonized by the Europeans nor closed off in the name of tradition.

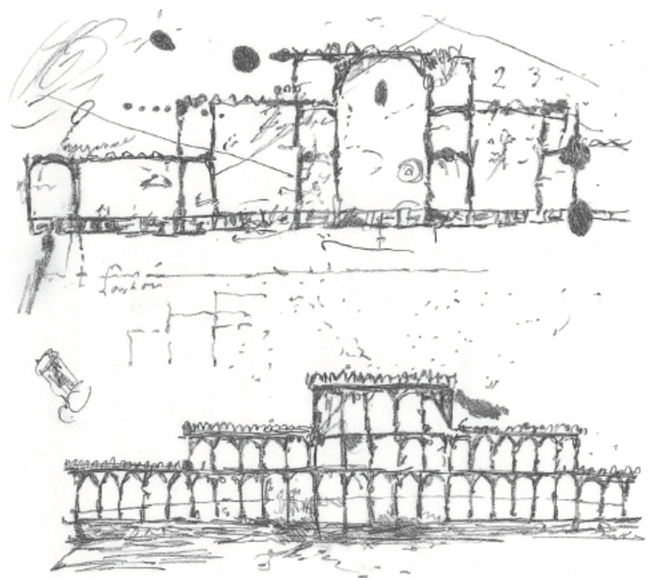


Pyramid building, a project for a cannon forge,
Claude Nicolas Ledoux (1706–1836)



Facsimile of Nishimura Shigenaga's *Interior of a Kabuki Theater*, eighteenth century

1900 CE

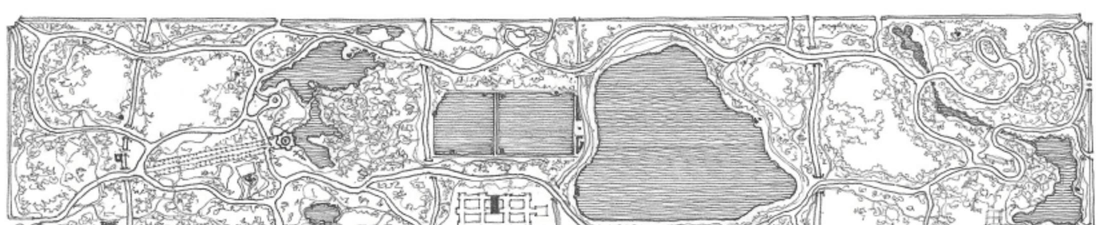


Sir Joseph Paxton's sketch for the Crystal Palace, London, 1850

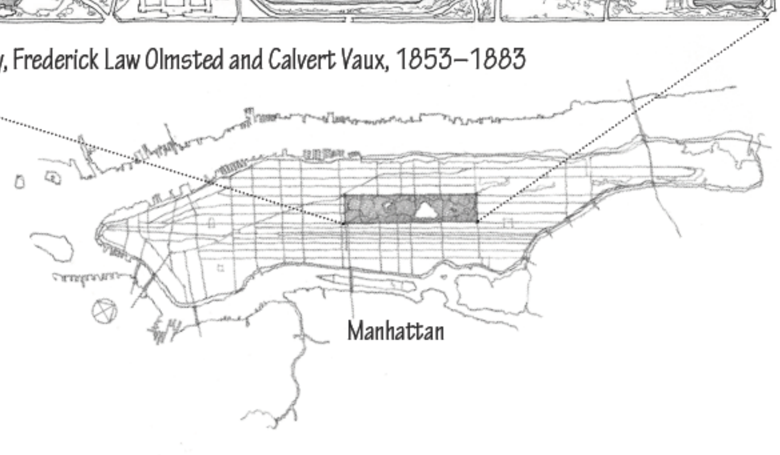
Between 1840 and 1900, the world's land area controlled by the European colonial powers rose from 60 to 91 percent, driven by a systematic policy of colonial expansion. This expansion served to raise cash crops and fueled the industrialization back home. France, however, had fallen behind. By the end of the nineteenth century, their yield from the colonies had risen only slightly, while the cost of running the empire had escalated significantly. For England, on the other hand, colonization ushered in an era of unbridled prosperity, making it the undisputed world power, especially after China was brought down in the middle of the nineteenth century through a policy of military action, political intimidation, and forced opiumization. By the late nineteenth century, England could act with impunity around the world. It invaded Egypt in 1882 to control the Suez Canal and South Africa in 1899 to take over the gold mines. By the turn of the century, England's wealth set it up for a showdown with Germany, which did not have a colonial empire but had industrialized heavily beginning late in the nineteenth century. The second half of the nineteenth century, because of the long rule of Queen Victoria (r. 1837–1901), has fittingly been called the Victorian era.

Textile design by William Morris

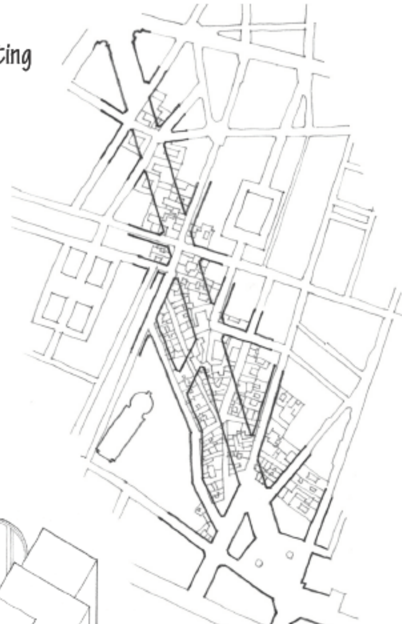
Political philosophers, Karl Marx (1818–1883) in particular, shed light on the emergence of the increasingly tight relationship between government, power, and capital. Whereas Marx exposed the inner workings of capitalism, Charles Darwin (1809–1882) brought out the inner workings of natural selection. In the arts, the young generation of the 1880s, led among others by William Morris (1834–1896), began to rebel against the dehumanization of industrial production and the strictures of English society and demanded a simpler and, for them, more authentic way of producing art and craft. Frederick Law Olmsted (1822–1903) in the United States led a movement to bring nature back into architectural and urban design considerations.



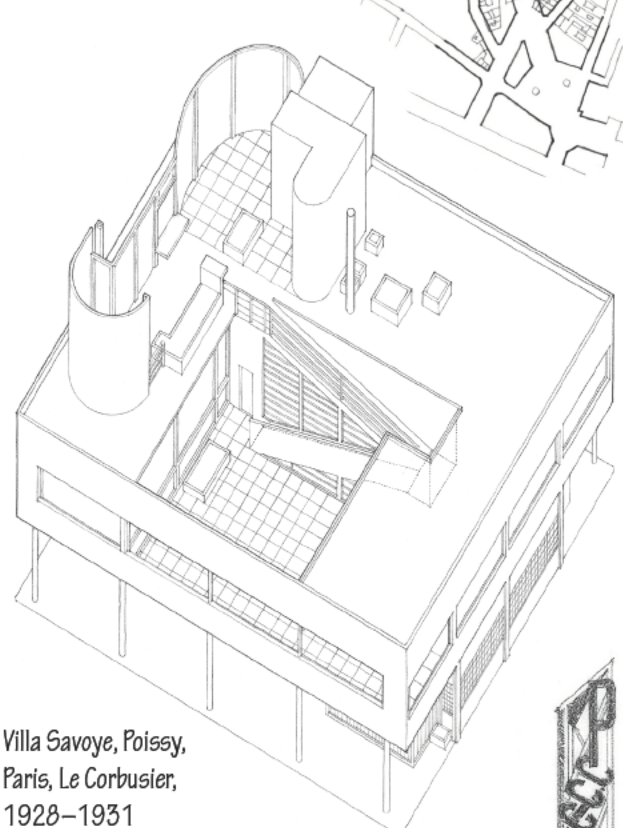
Plan of Central Park, New York City, Frederick Law Olmsted and Calvert Vaux, 1853–1883



Manhattan



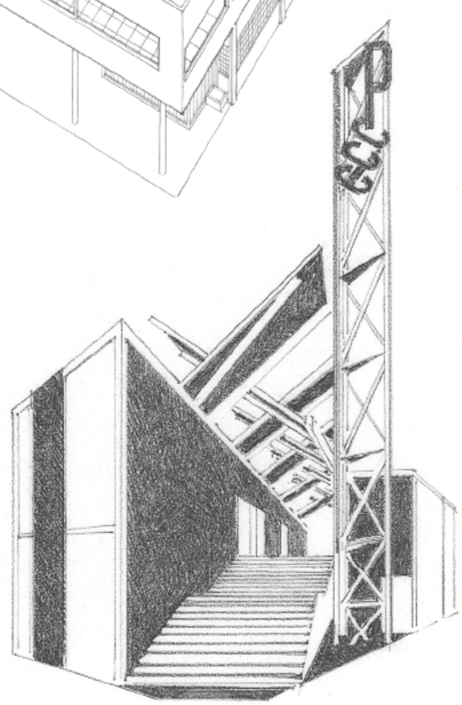
Part of Georges-Eugene Hausmann's vision for renovating Paris, 1853–1870



Villa Savoye, Poissy, Paris, Le Corbusier, 1928–1931

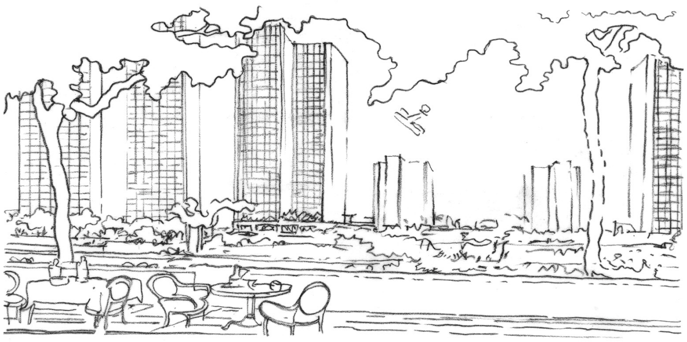
Although England played the dominant role economically and in matters of domestic architecture, the French began to assert themselves in matters of urban culture. The center of Paris was thoroughly rebuilt under Napoleon III and became the model for urban redesigns in Europe and around the world. Argentina's exports, for example, may have largely gone to England, but when it came to streets and public buildings, the elite turned to Parisian models. The French Beaux-Arts, as a voice that combined bourgeois elegance and professional expertise (also known as the Second Empire style), was an international movement in its own right.

A perceptible shift occurred around the turn of the century, revolving around a split between public and private. Public architecture tended to be elaborate, formal, and yielding to the ornamental, whereas domestic architecture came to be dominated by the calmer ethos of the arts-and-crafts movement. Both, however, should be seen as part of the developing modernity of the times. Radical experiments were undertaken to invent new architectural styles and possibilities. With the development of art nouveau and expressionism in Europe and the inventions of Frank Lloyd Wright in the United States, the foundations of the world of modern architecture were set in place. In fact, between 1890 and 1910, architecture was significantly more experimental than it was in the 1930s. New materials like concrete were used to build new types of enclosures. The steel frame, developed in Chicago and New York, was challenging the norms of urban living and work. Particularly important to the transition to modernism was the expressionist movement, which in the span of the years before and after World War I articulated the first coherent alternative —although sometimes fanciful—to traditional architectural practices. By the mid-1920s, however, the modern movement, as it is generally understood, began to take shape in the buildings and theorizing of Walter Gropius, Ludwig Mies van der Rohe, and Le Corbusier, among many others, with the Bauhaus in Germany, the de Stijl architects in Holland, and the constructivists in the newly formed Union of Soviet Socialist Republics (USSR, or Soviet Union) being the flash points for the developing aesthetic.



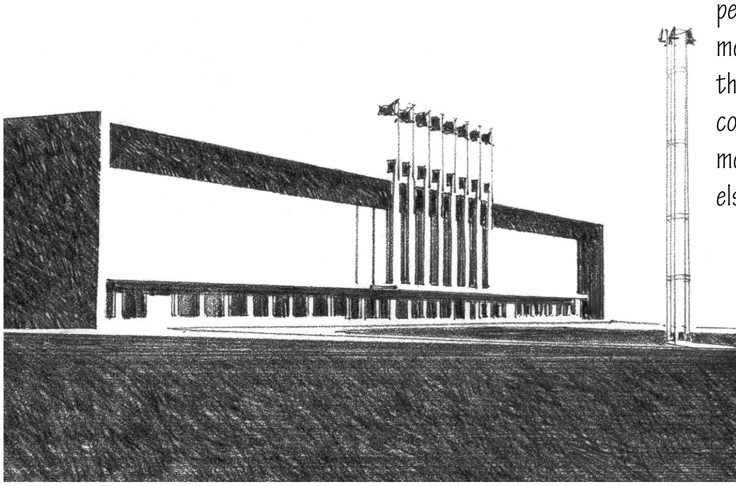
Soviet Pavilion, 1925 International Exposition, Paris, Konstantin Melnikov

1950 CE

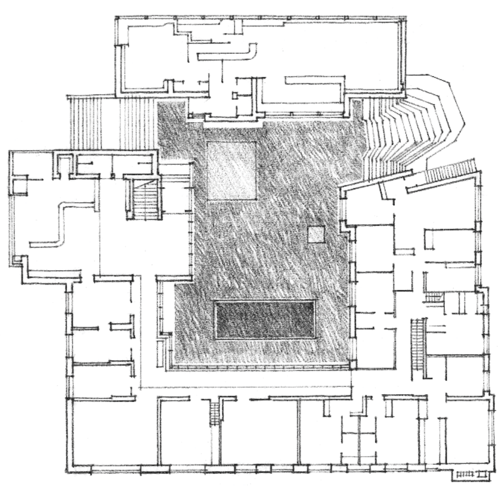


Le Corbusier's vision for the residential quarter of the Radiant City, 1935

The landmarks in the early formation of the Modern Movement included Walter Gropius's new school of design, the Bauhaus (founded in 1919); Le Corbusier's book *Vers une Architecture* (*Towards a New Architecture*), first published in 1923; and Ludwig Mies van de Rohe's Weissenhof Siedlung Exhibition in 1927. CIAM (Congrès Internationaux d'Architecture Moderne), founded in 1928, also played an important role as it quickly grew into an organization with dozens of members from around the world, all committed to the ideals of bringing functionalism and rationalism to building and urban planning. Modernism's appeal was, however, not universal. Germany under Hitler and the USSR under Joseph Stalin rejected Modernism in favor of a monumental neoclassical style, opening up deep rifts between modernists and traditionalists. Even in France, despite the work and efforts of Le Corbusier, there were only a handful of modernist buildings before World War II. During this period the Fascists in Italy were unusual in so far as they readily adopted modern architecture—though still classicizing in nature—to express their nationalist ideals. Whereas in Europe Modernism was highly contested, it was embraced in Ankara and Tel Aviv, the places where more modernist architecture could be found during this period than anywhere else in the world.

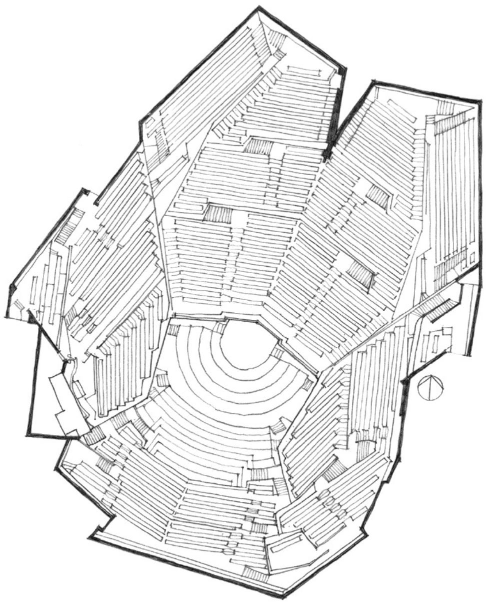


Exhibition hall for the Izmir International Fair, Turkey, Sevki Balmumcu, 1936



Plan of Säynätsalo Town Hall, Finland, Alvar Aalto, 1949–1952

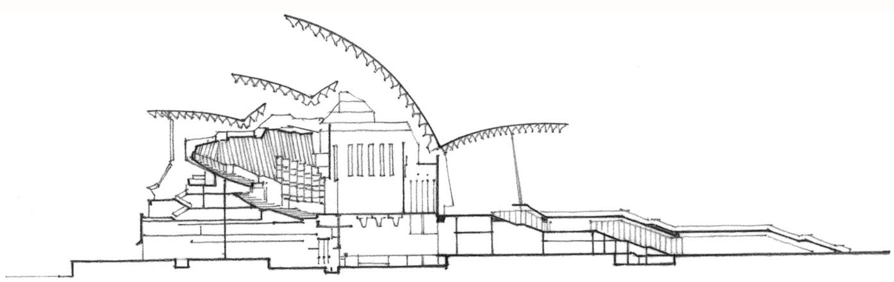
It was really only after World War II that modern architecture came into its own and began to make significant and sustained contributions to urban space such as the Säynätsalo Town Hall in Finland and the Pragerstrasse in Dresden—then there were two new capitals, Chandigarh in India and Brasília in Brazil. The US had only hesitatingly embraced Modernism. That changed, however, with the move of Mies van der Rohe to teach at the Illinois Institute of Technology in Chicago and of Walter Gropius at Harvard University. With academic acceptance established, the modernist ethos was on the way. Corporations in particular eagerly adopted the new style with its sleek and anonymous surfaces such as the Lever House (1950–1952), designed by the firm of Skidmore Owings and Merrill (SOM), and the Seagram Building by Mies van der Rohe, both in New York City, setting the tone. SOM soon specialized in designing corporate headquarters in the United States and abroad, and became one of the largest architectural firms of the time.



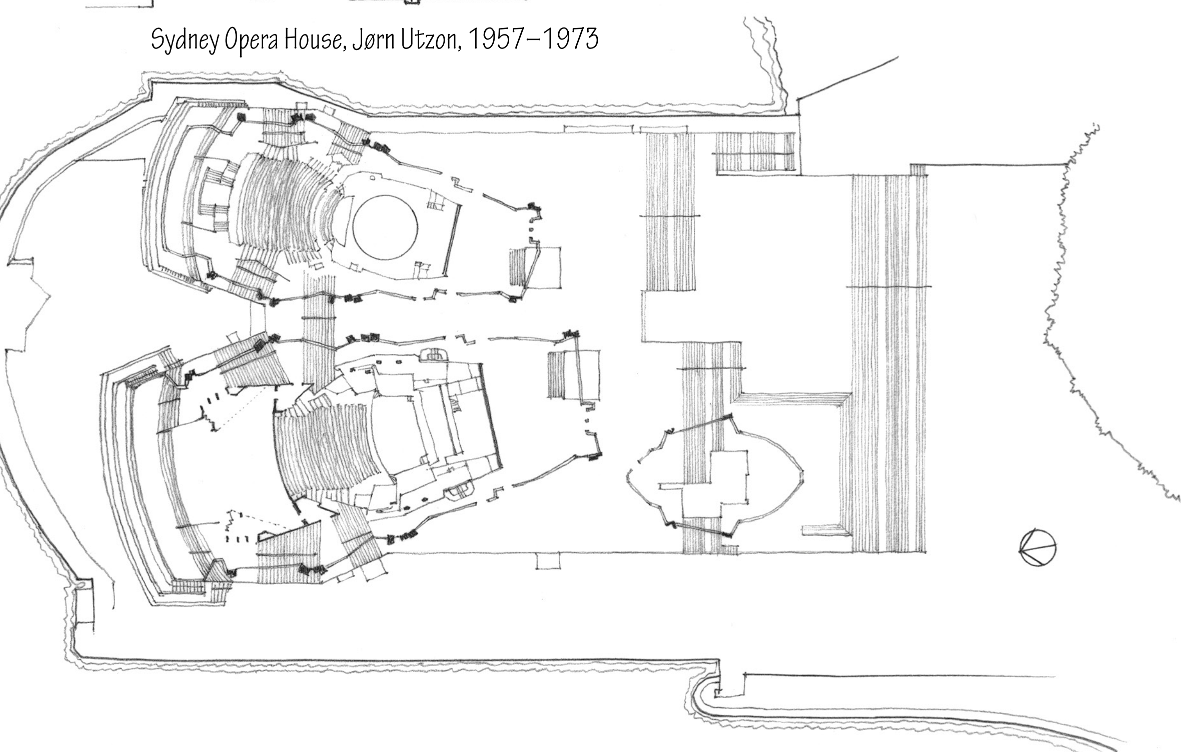
Plan of the Berlin Philharmonic Hall, Hans Scharoun, 1956–1963

The relative coherency and anonymity of post–World War II architecture was offset by prestige commissions that introduced bold and exciting forms into the urban context: the Guggenheim Museum (Frank Lloyd Wright, 1956–1959), the Berlin Philharmonic Hall (Hans Scharoun, 1956–1963), the Sydney Opera House (Jørn Utzon, 1957–1973).

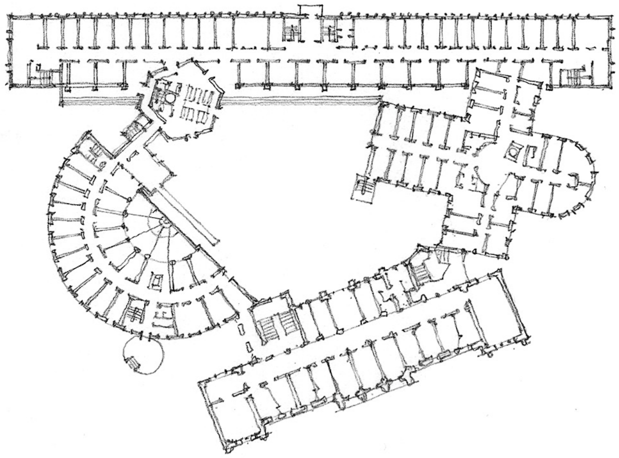
By the 1960s, the conventions of Modernism were breaking down and architects began experimenting with large scales and simple forms in a style that came to be known as Brutalism, as exemplified by the Yamanashi Press and Broadcasting Center (Kenzo Tange, 1964–1967) in Kofu, Japan, and the Royal National Theatre (Denys Lasdun, 1976) in London, buildings with exaggerated forms and large-scale massing. At that time, architecture's claims to universality, its anti-contextual aesthetic, and the drabness of housing projects started to come under heavy criticism. A group from England, which came to be known by the banner of the journal it founded, Archigram, promoted an architecture influenced by Pop Art that was mobile, flexible, transitory, and youth-oriented.



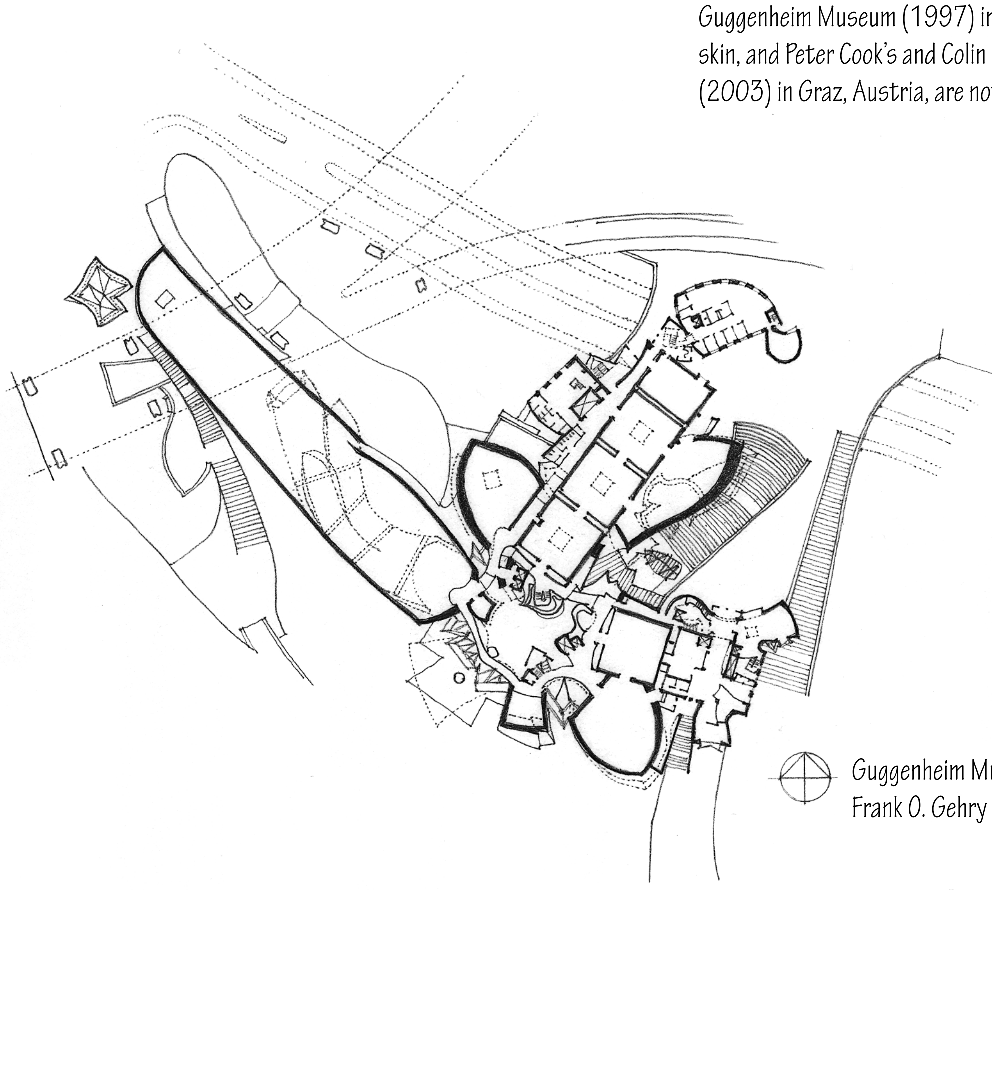
Sydney Opera House, Jørn Utzon, 1957–1973



Social Science Research Center, Berlin, 1981, James Stirling



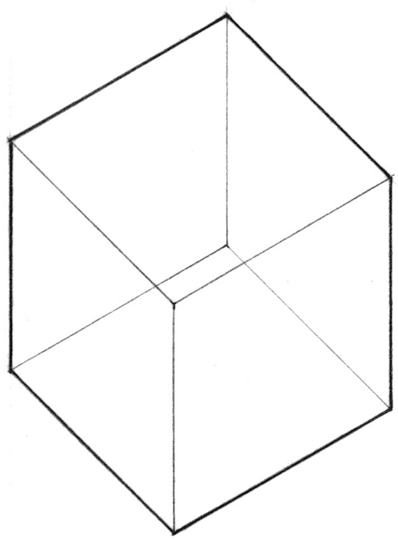
These and other critiques developed into a larger movement that in the 1970s came to be known as Postmodernism. Some architects, like Aldo Rossi in Italy, hoped for a return to history; others, like Robert Venturi and Denise Scott Brown, sought out parody and irony; whereas Peter Eisenman in the United States and Oswald Mathias Ungers in Germany aimed for a formalism more rigorous than even that of the modernists. The most enduring aspect of Postmodernism was its call for a heightened awareness of a building's context, but how context was to be defined was much debated and varied from Daniel Libeskind's highly abstract Jewish Museum in Berlin (2001) to the efforts of Prince Charles of England to reawaken an interest in traditional styles. In the 1990s, in opposition to the conservative tenor of much architectural production, a group of avant-garde architects, among them Rem Koolhaas from Holland, called for a revival of modernist forms and abstractions. Advances in technology and computers also enabled architects to build structures that in a previous decade would have been unthinkable. Frank Gehry's Guggenheim Museum (1997) in Bilbao, Spain, with its curved titanium skin, and Peter Cook's and Colin Fournier's blue, bubble-shaped Kunsthaus (2003) in Graz, Austria, are noted examples.

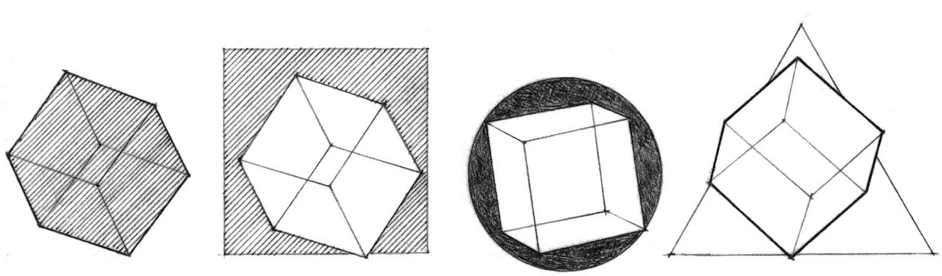


Guggenheim Museum, Bilbao, Spain, 1991–1997, Frank O. Gehry

4 Fundamentals of Architecture:

Form

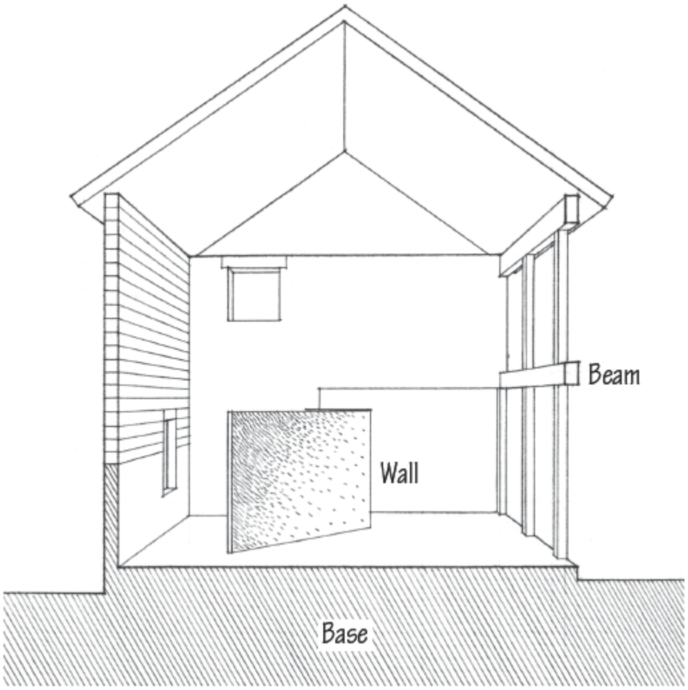




Tectonics

Form has several considerations in architecture. It can be addressed compositionally, as it pertains to construction, or in terms of material or material characteristics.

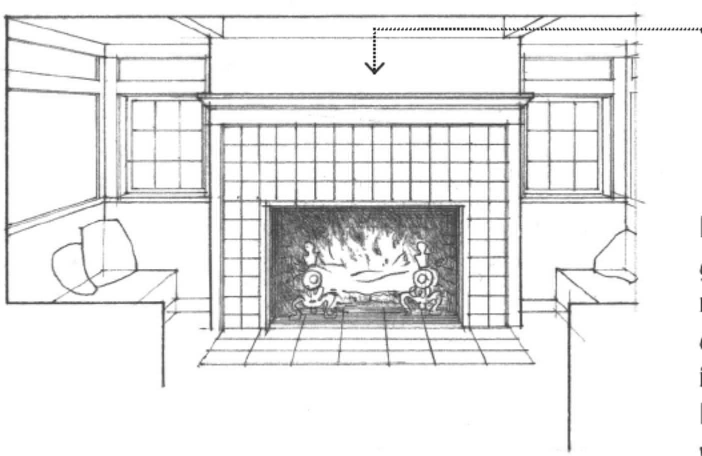
Compositionally, architecture can be understood as a mass/void relationship. In thinking of architecture in this way, the void is area that can be inhabited—space. The mass is occupied by the physical presence of the building—form. Form refers to the physical character of architecture. It defines the limits of space and determines ways it might be inhabited.



Especially in the early stages of the design process, parts of a building can be understood generically. A system for the way generic forms are assembled in order to define the space is called *tectonics*, from the Greek *tektonikos*, meaning pertaining to construction. It is a logical system that divides formal elements into types based upon their proportions; this translates into how those forms might be used in a design.

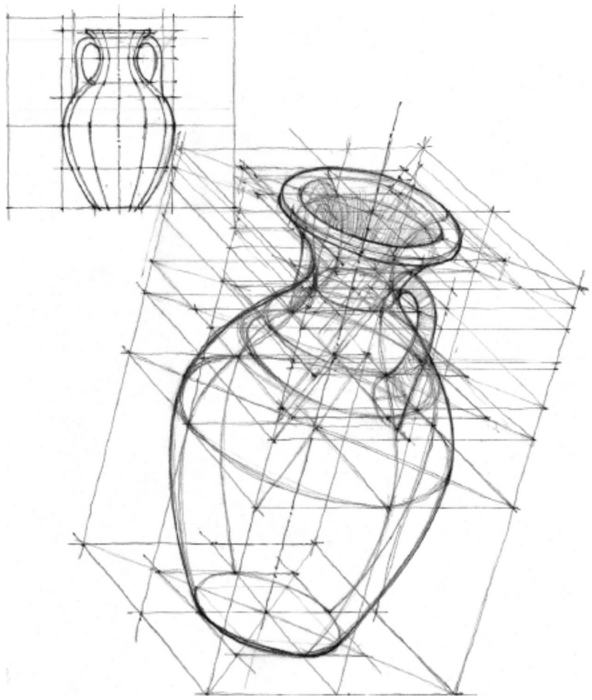
The following are the four tectonic elements:

- Mass is a form that is proportionally similar in all dimensions (base or plinth).
- Plane is a form that is proportionally similar in two dimensions and significantly smaller in the third (wall).
- Frame is a form that is proportionally similar in two dimensions and significantly longer in the third (beam).
- Hearth is any formal element that acts as a focal point. Because the hearth would provide heat, the ability to cook, and define a place for social interaction, it was most frequently primary to any architectural idea, and central to any spatial composition.



Later, construction knowledge would allow the architect to translate a generic, compositional understanding of form into one that incorporated material, and structural characteristics. Construction is also an ever-present concern of architecture. In addition to the limitations imposed by structural loads and material strength, construction also has the capacity to inform the way space is perceived. Color, texture, visual weight, opacity, and reflectivity among others are material characteristics that influence the way people occupy and use a space.

Architects use this knowledge of form to affect their design thinking. They continually discover new possibilities for design as technology advances and material knowledge expands, making possible new building forms that were once only imagined.

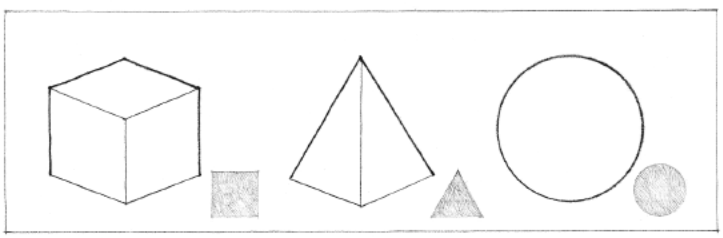


Characteristics of Form

Form is an inclusive term that has several meanings. It may refer to an external appearance that can be recognized, like that of a chair or the human body that sits in it. It may also allude to a particular condition in which something acts or manifests itself, such as when we speak of water in the form of ice or steam.

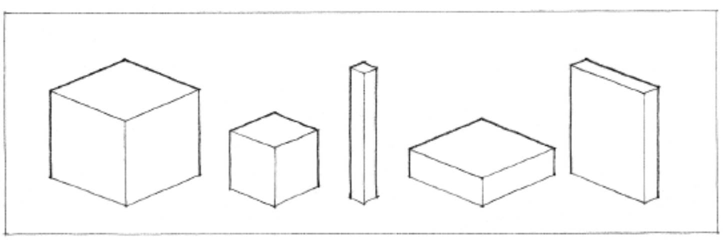
In art and design, we often use the term to denote the formal structure of a work—the manner of arranging and coordinating the elements and parts of a composition so as to produce a coherent image. In the context of this study, form suggests reference to both internal structure and external outline and the principle that gives unity to the whole.

While form often includes a sense of three-dimensional mass or volume, shape refers more specifically to the essential aspect of form that governs its appearance—the configuration or relative disposition of the lines or contours that delimit a figure or form.



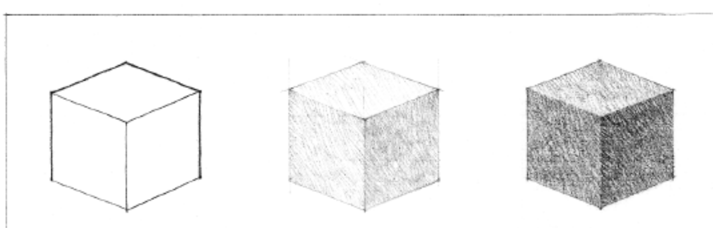
Shape

The characteristic outline or surface configuration of a particular form.
Shape is the principal aspect by which we identify and categorize forms.
In addition to shape, forms have visual properties of size, shape, color, and texture.



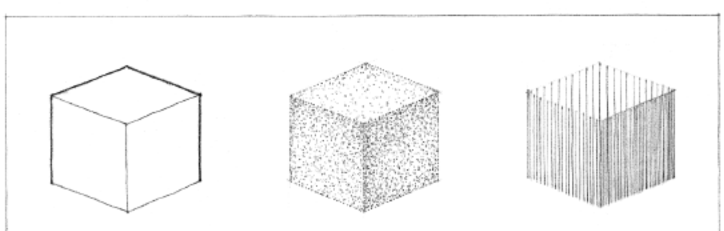
Size

Size is the physical dimensions of length, width, and depth of a form. While these dimensions determine the proportions of a form, its scale is determined by its size relative to other forms in its context.



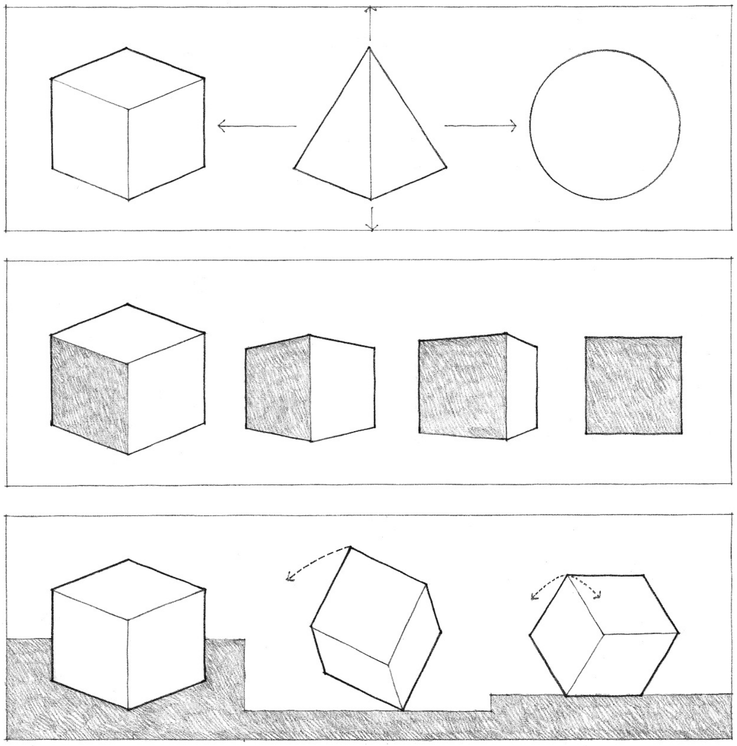
Color

Color is a phenomenon of light and visual perception that may be described in terms of an individual's perception of hue, saturation, and tonal value. Color is the attribute that most clearly distinguishes a form from its environment. It also affects the visual weight of a form.



Texture

Texture is the visual and especially tactile quality given to a surface by the size, shape, arrangement, and proportions of the parts. Texture also determines the degree to which the surfaces of a form reflect or absorb incident light.

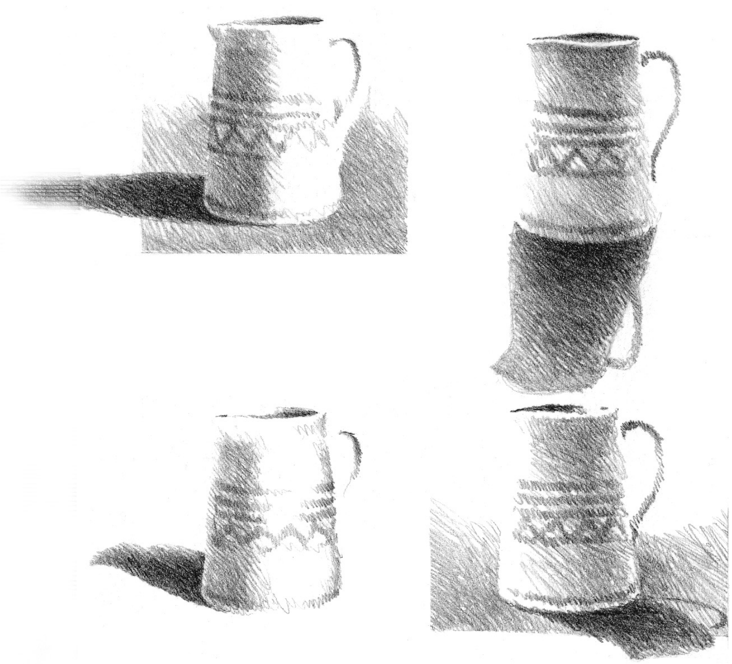


Forms also have relational properties that govern the pattern and composition of elements, including position, orientation, and visual inertia.

Position
Position is the location of a form relative to its environment or the visual field within which it is seen.

Orientation
Orientation is the direction of a form relative to the ground plane, the compass points, other forms, or to the person viewing the form.

Visual Inertia
Visual inertia is the degree of concentration and stability of a form. The visual inertia of a form depends on its geometry as well as its orientation relative to the ground plane, the pull of gravity, and the viewer's line of sight.



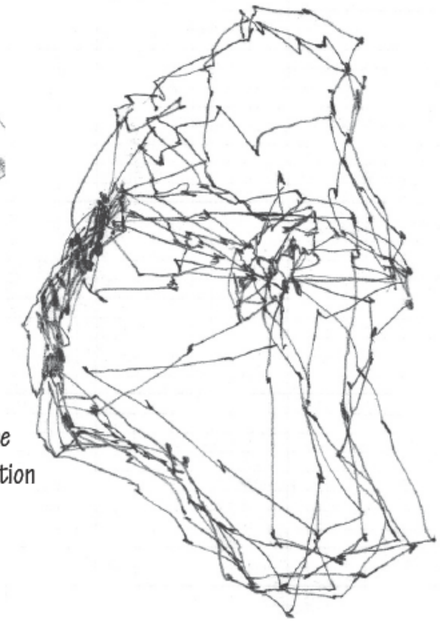
All of these properties of form are in reality affected by the conditions under which we view them.

- A changing perspective or angle of view presents different shapes or aspects of a form to our eyes.
- Our distance from a form determines its apparent size.
- The lighting conditions under which we view a form affects the clarity of its shape and structure.
- The visual field surrounding a form influences our ability to read and identify it.

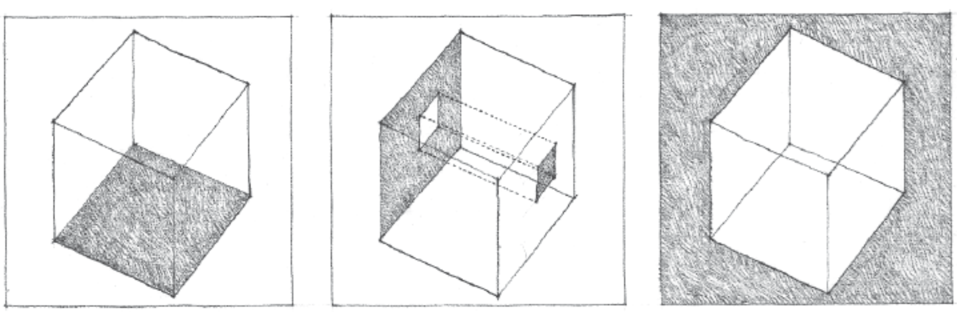
Shape

Shape refers to the characteristic outline of a plane figure or the surface configuration of a volumetric form. It is the primary means by which we recognize, identify, and categorize particular figures and forms. Our perception of shape depends on the degree of visual contrast that exists along the contour separating a figure from its ground or between a form and its field.

Bust of Queen Nefertiti



The pattern of eye movement of a person viewing the figure, from research by Alfred L. Yarbus of the Institute for Problems of Information Transmission in Moscow.

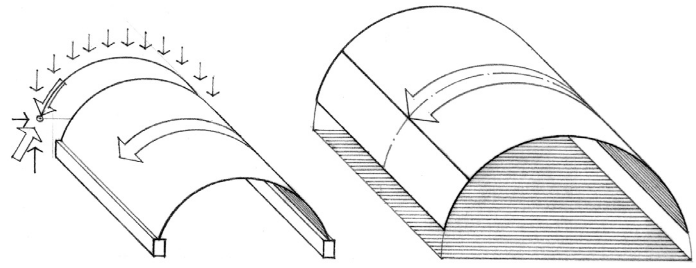


In architecture, we are concerned with the shapes of:

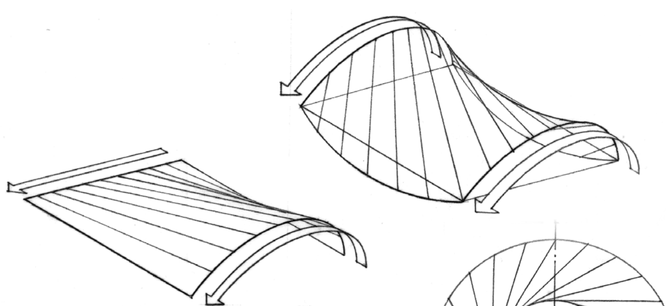
- Floor, wall, and ceiling planes that enclose space
- Door and window openings within a spatial enclosure
- Silhouettes and contours of building forms

Surface

In the transition from the shapes of planes to the forms of volumes is situated the realm of surfaces. "Surface" first refers to any figure having only two dimensions, such as a flat plane. The term, however, can also allude to a curved two-dimensional locus of points defining the boundary of a three-dimensional solid. There is a special class of the latter that can be generated from the geometric family of curves and straight lines. This class of curved surfaces includes the following:

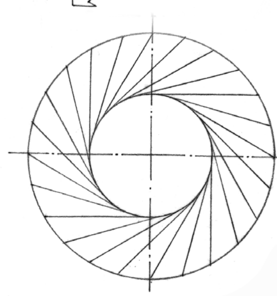


- Cylindrical surfaces are generated by sliding a straight line along a plane curve or vice versa. Depending on the curve, a cylindrical surface may be circular, elliptic, or parabolic. Because of its straight line geometry, a cylindrical surface can be regarded as being either a translational or a ruled surface.



- Translational surfaces are generated by sliding a plane curve along a straight line or over another plane curve.

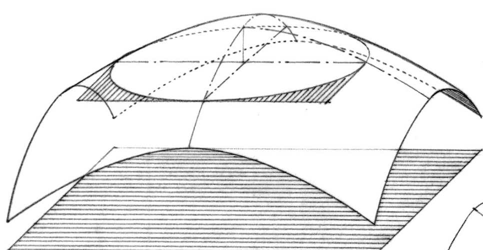
- Ruled surfaces are generated by the motion of a straight line. Because of its straight line geometry, a ruled surface is generally easier to form and construct than a rotational or translational surface.

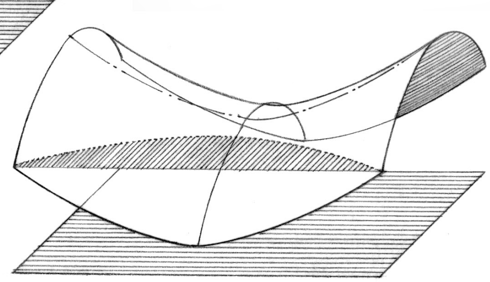


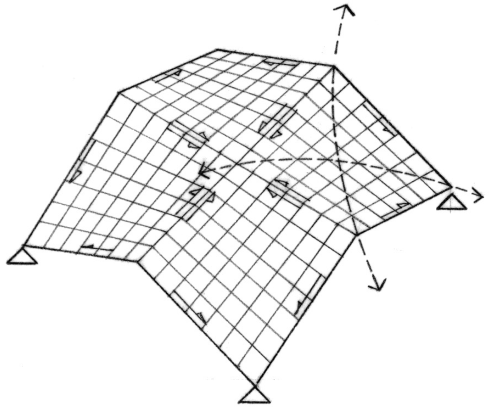
- Rotational surfaces are generated by rotating a plane curve about an axis.

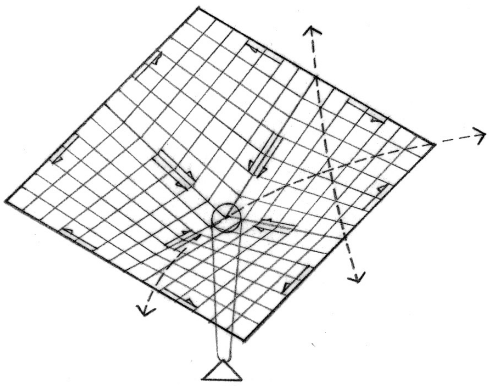
- Paraboloids are surfaces all of whose intersections by planes are either parabolas and ellipses or parabolas and hyperbolas. Parabolas are plane curves generated by a moving point that remains equidistant from a fixed line and a fixed point not on the line. Hyperbolas are plane curves formed by the intersection of a right circular cone with a plane that cuts both halves of the cone.

- Hyperbolic paraboloids are surfaces generated by sliding a parabola with downward curvature along a parabola with upward curvature, or by sliding a straight line segment with its ends on two skew lines. It can, thus, be considered to be both a translational and a ruled surface.

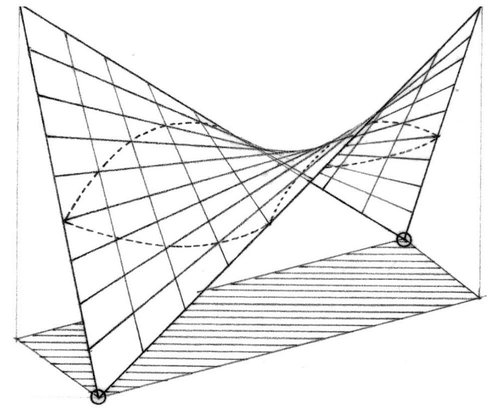


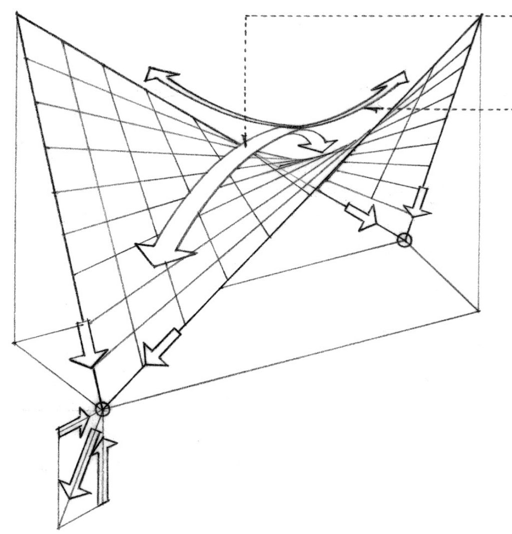


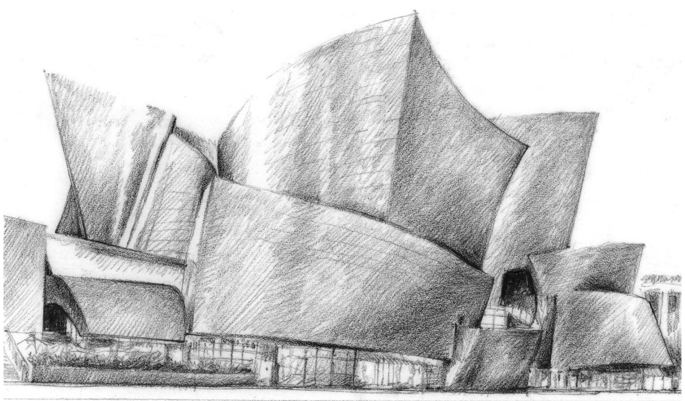


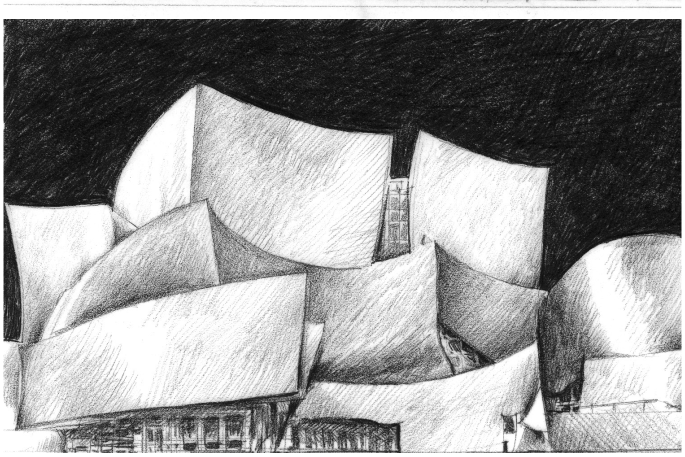


- Saddle surfaces have an upward curvature in one direction and a downward curvature in the perpendicular direction. Regions of downward curvature exhibit archlike action, while regions of upward curvature behave like a cable structure. If the edges of a saddle surface are not supported, beam behavior may also be present.







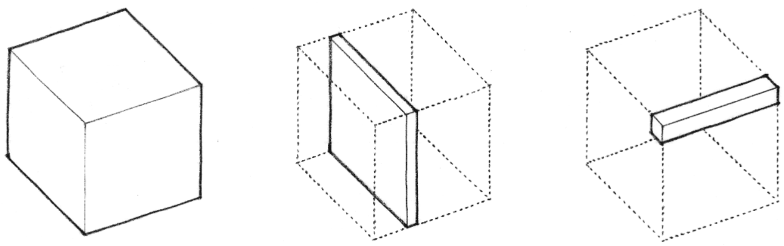


The geometric basis for these curved surfaces can be effectively used in digital modeling as well as in the description, fabrication, and assembly of curvilinear architectural elements and components. The fluid quality of curved surfaces contrasts with the angular nature of rectilinear forms and is appropriate for describing the form of shell structures as well as non-load-bearing elements of enclosure. Symmetrical curved surfaces, such as domes and barrel vaults, are inherently stable. Asymmetric curved surfaces, on the other hand, can be more vigorous and expressive in nature. Their shapes change dramatically as we view them from different perspectives.

Walt Disney Concert Hall, Los Angeles, California, 1987–2003, Frank O. Gehry & Partners

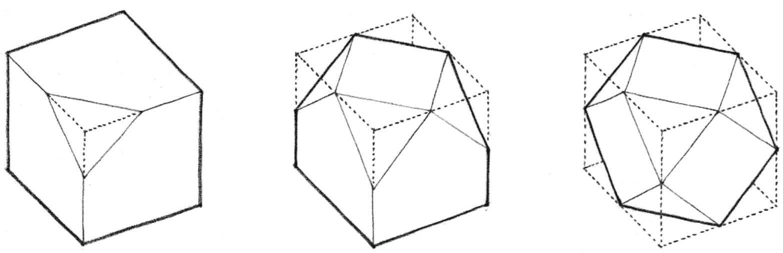
Transformation

All other forms can be understood to be transformations of the primary solids, variations that are generated by the manipulation of one or more dimensions or by the addition or subtraction of elements.



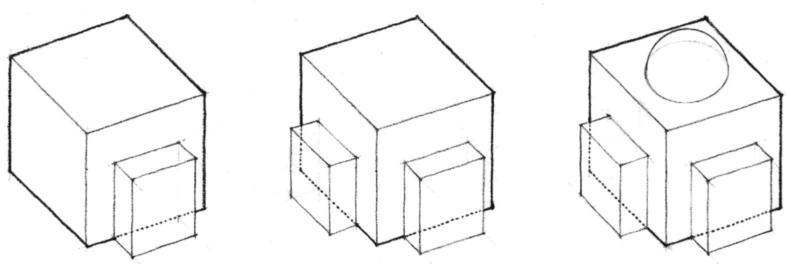
Dimensional Transformation

A form can be transformed by altering one or more of its dimensions and still retain its identity as a member of a family of forms. A cube, for example, can be transformed into similar prismatic forms through discrete changes in height, width, or length. It can be compressed into a planar form or be stretched out into a linear one.



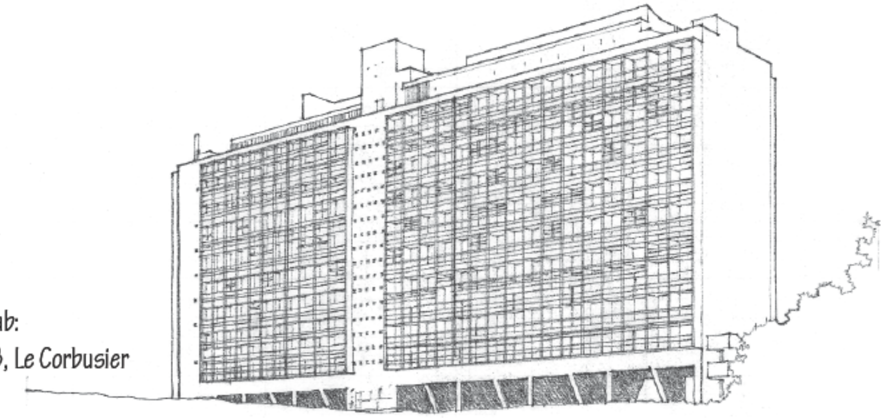
Subtractive Transformation

A form can be transformed by subtracting a portion of its volume. Depending on the extent of the subtractive process, the form can retain its initial identity or be transformed into a form of another family. For example, a cube can retain its identity as a cube even though a portion of it is removed, or be transformed into a series of regular polyhedrons that begin to approximate a sphere.

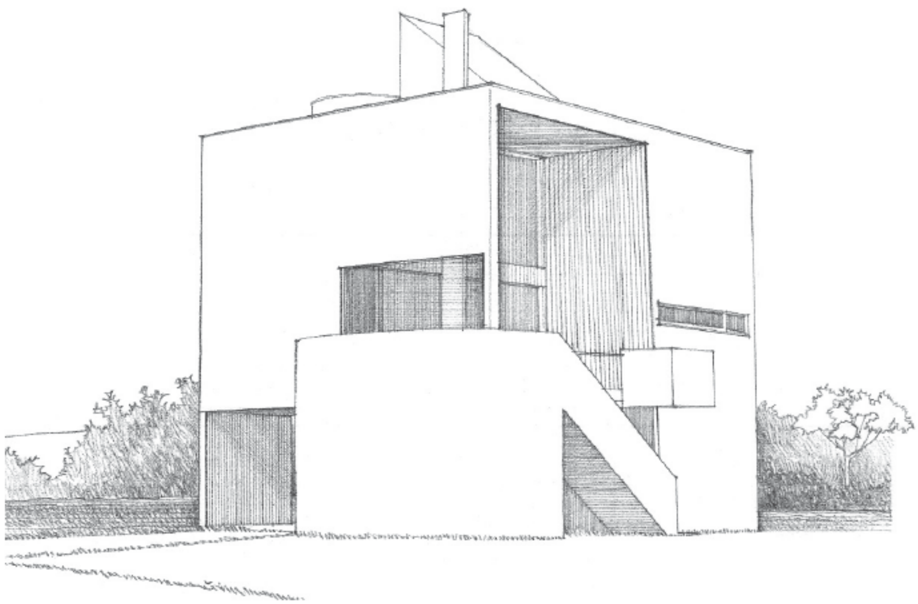


Additive Transformation

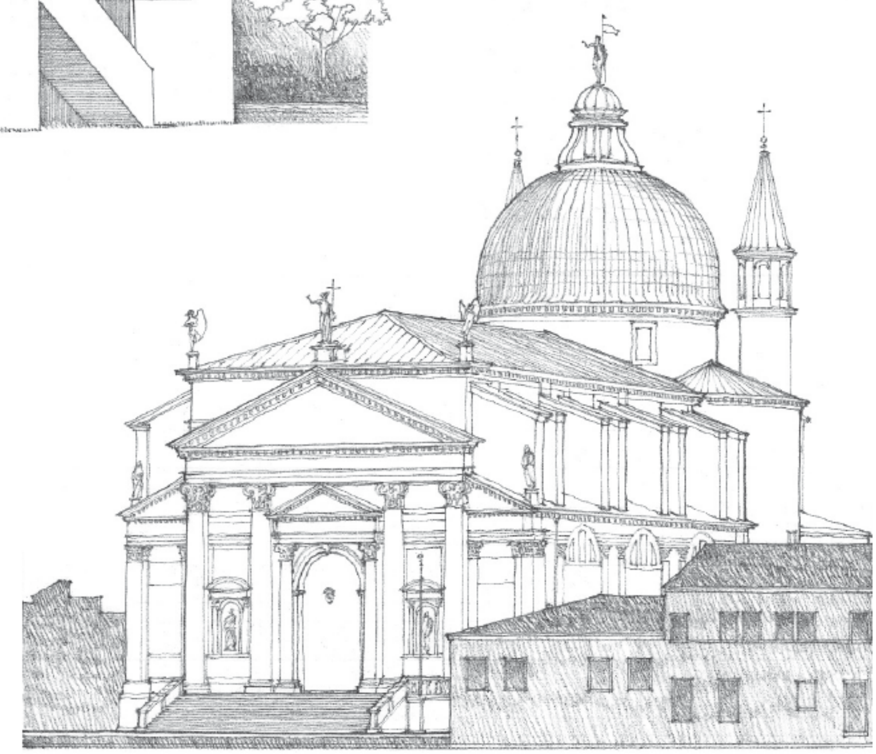
A form can be transformed by the addition of elements to its volume. The nature of the additive process and the number and relative sizes of the elements being attached determine whether the identity of the initial form is altered or retained.



Dimensional transformation of a cube into a vertical slab:
Unité d'Habitation, Firminy-Vert, France, 1963–1968, Le Corbusier

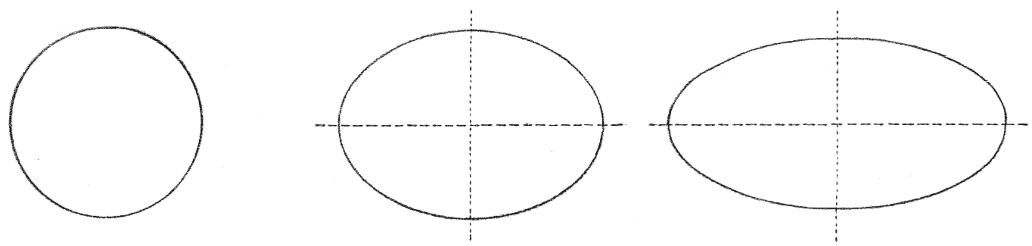


Subtractive transformation creating volumes of space:
Gwathmey Residence, Amagansett, New York, 1967,
Charles Gwathmey/Gwathmey Siegel

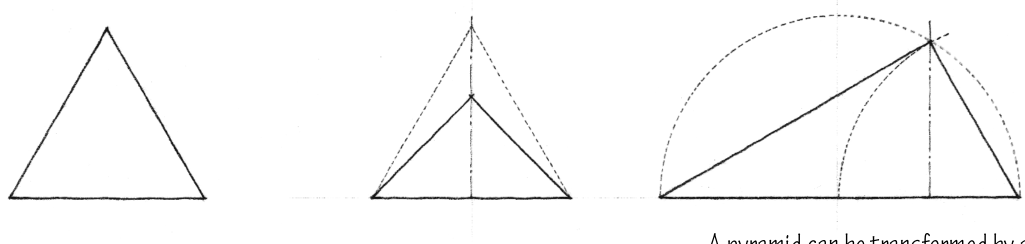


Additive transformation of a parent form by the attachment of subordinate parts:
Il Redentore, Venice, 1577–1592, Andrea Palladio

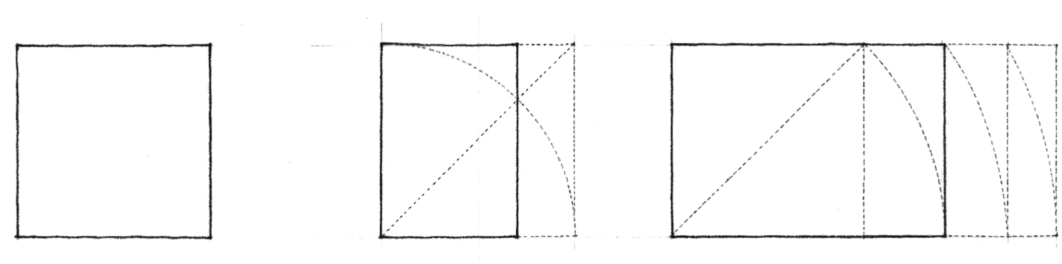
Dimensional Transformation



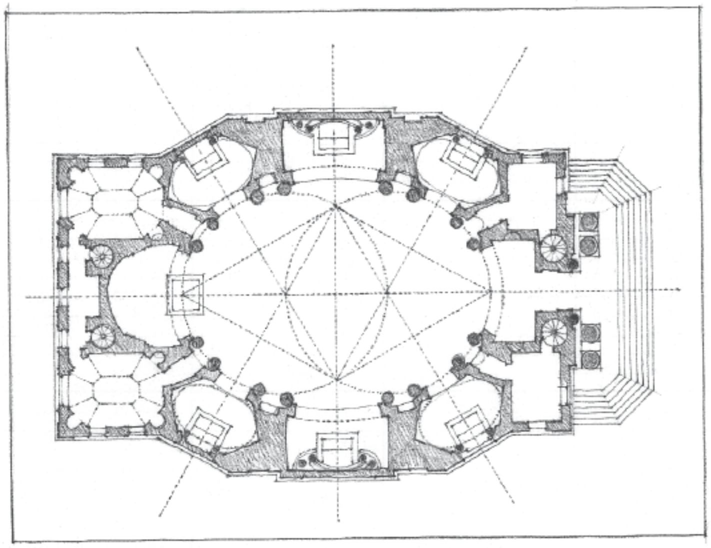
A sphere can be transformed into any number of ovoid or ellipsoidal forms by elongating it along an axis.



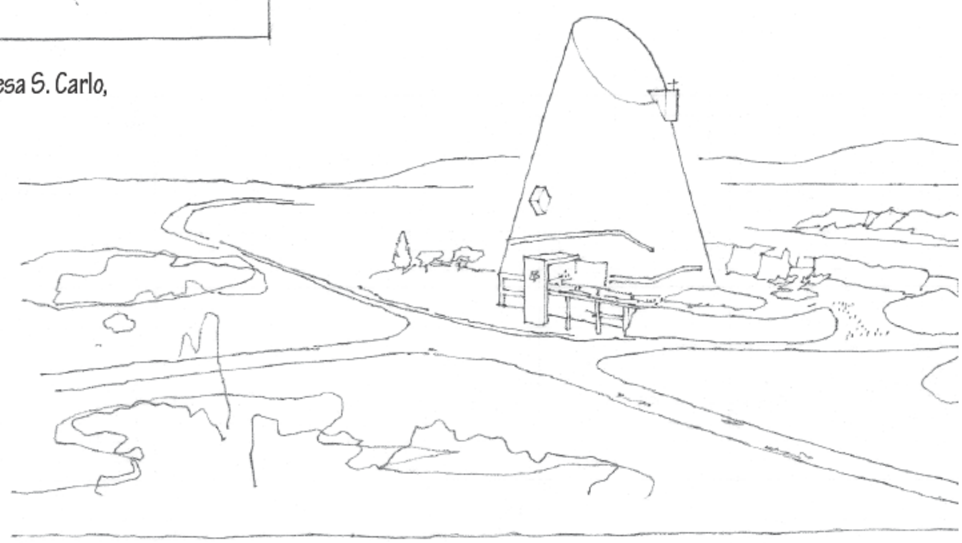
A pyramid can be transformed by altering the dimensions of the base, modifying the height of the apex, or tilting the normally vertical axis.



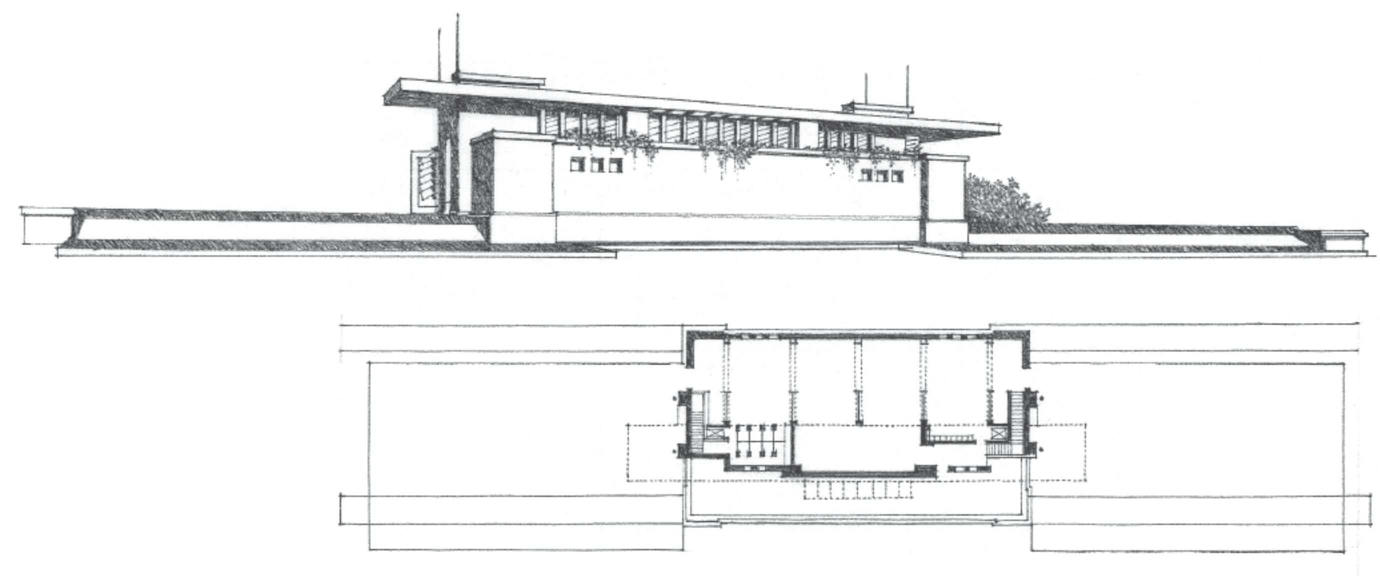
A cube can be transformed into similar prismatic forms by shortening or elongating its height, width, or depth.



Plan of an Elliptical Church, Pensiero Della Chiesa S. Carlo,
Project, 17th century, Francesco Borromini



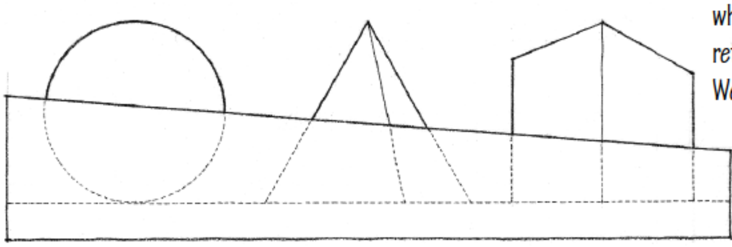
St. Pierre, Firminy-Vert, France, 1965, Le Corbusier

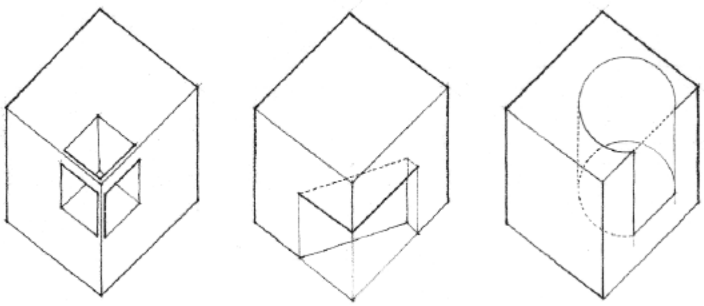


Project for Yahara Boat Club, Madison, Wisconsin, 1902, Frank Lloyd Wright

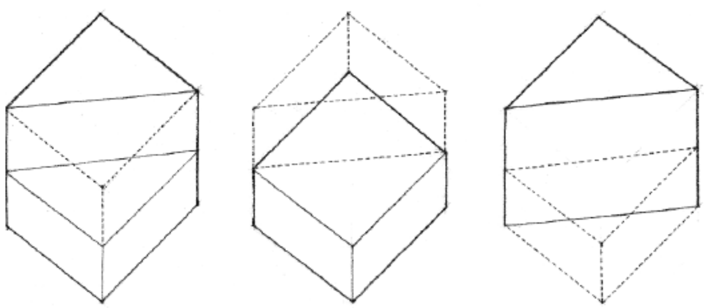
Subtractive Form

We search for regularity and continuity in the forms we see within our field of vision. If any of the primary solids is partially hidden from our view, we tend to complete its form and visualize it as if it were whole because the mind fills in what the eyes do not see. In a similar manner, when regular forms have fragments missing from their volumes, they retain their formal identities if we perceive them as incomplete wholes. We refer to these mutilated forms as subtractive forms.



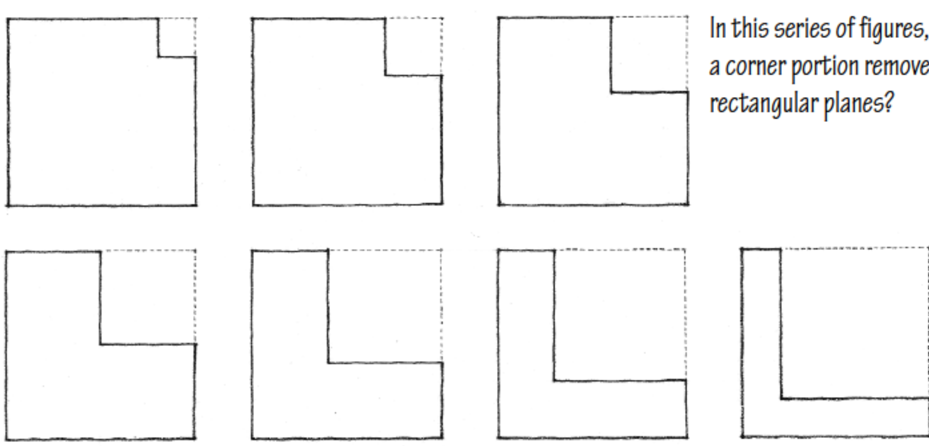


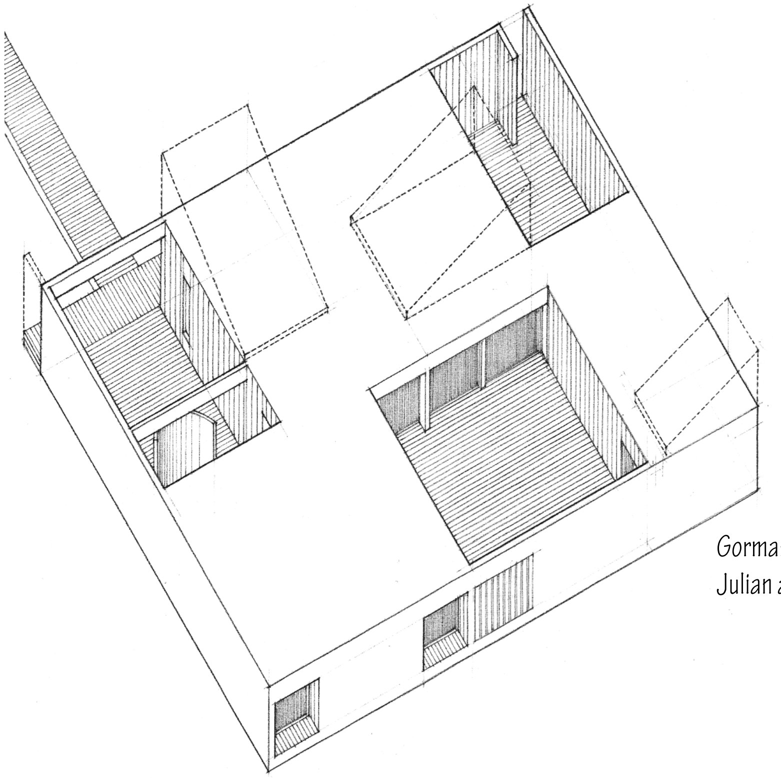
Because they are easily recognizable, simple geometric forms, such as the primary solids, adapt readily to subtractive treatment. These forms will retain their formal identities if portions of their volumes are removed without deteriorating their edges, corners, and overall profile.



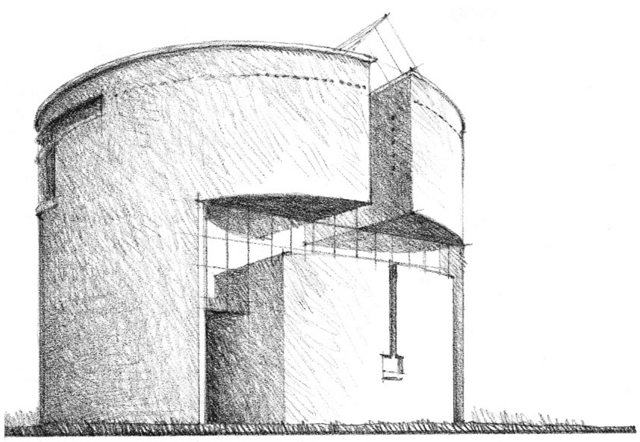
Ambiguity regarding the original identity of a form will result if the portion removed from its volume erodes its edges and drastically alters its profile.

In this series of figures, at what point does the square shape with a corner portion removed become an L- shaped configuration of two rectangular planes?



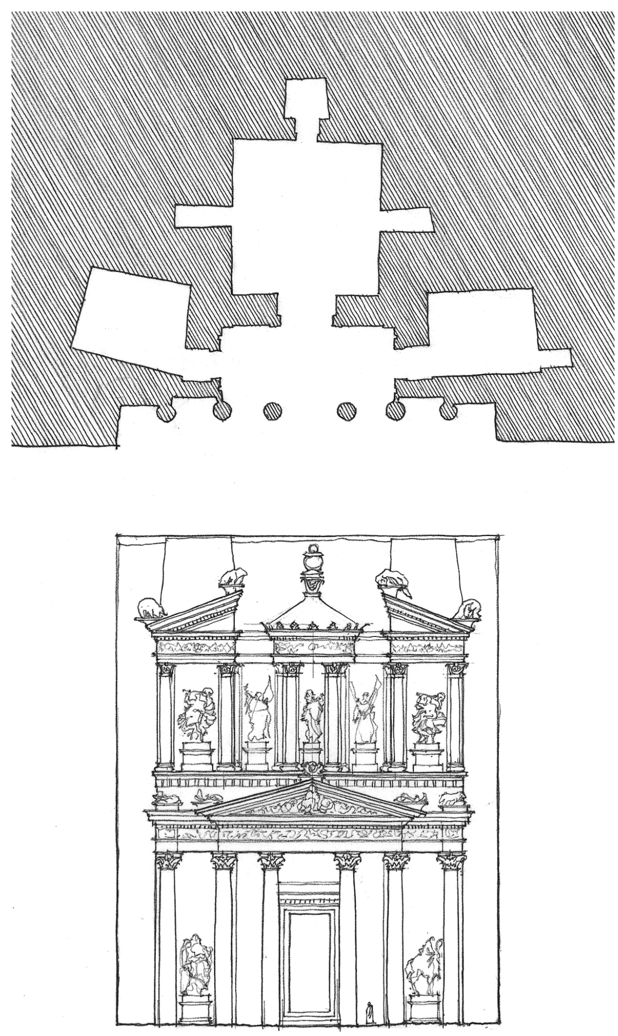


Gorman Residence, Amagansett, New York, 1968,
Julian and Barbara Neski



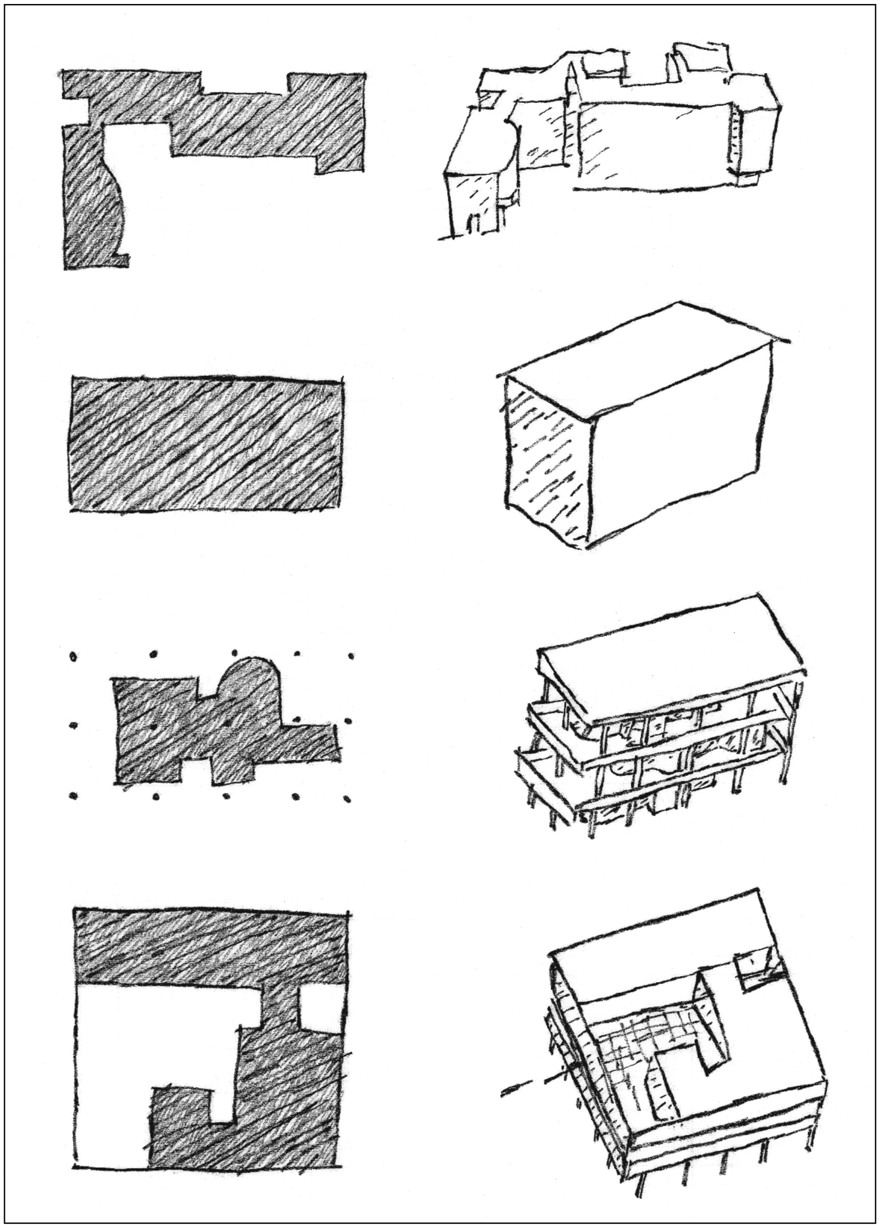
House at Stabio, Switzerland, 1981, Mario Botta

Spatial volumes may be subtracted from a form to create recessed entrances, positive courtyard spaces, or window openings shaded by the vertical and horizontal surfaces of the recess.



Khasneh al Faroun, Petra, first century CE

In his *Five Points of Architecture* (1929), Le Corbusier comments on form:



After a sketch, *Four House Forms*, in Le Corbusier's *Five Points of Architecture*

"Cumulative Composition
- additive form
- a rather easy type
- picturesque; full of movement
- can be completely disciplined by classification and hierarchy"

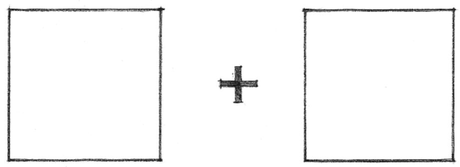
"Cubic Compositions (Pure Prisms)
- very difficult (to satisfy the spirit)"

"very easy
- (convenient combining)"

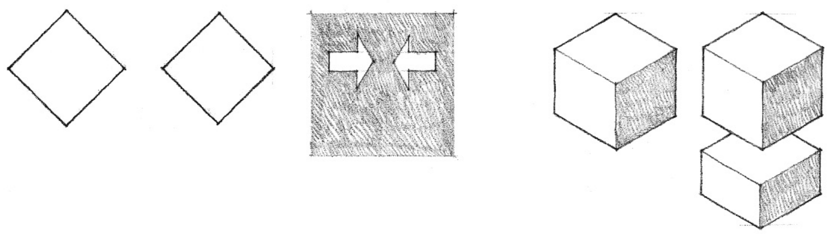
"subtractive form
- very generous
- on the exterior an architectural will is confirmed
- on the interior all functional needs are satisfied (light penetration, continuity, circulation)"

Grouping Forms

While a subtractive form results from the removal of a portion of its original volume, an additive form is produced by relating or physically attaching one or more subordinate forms to its volume.

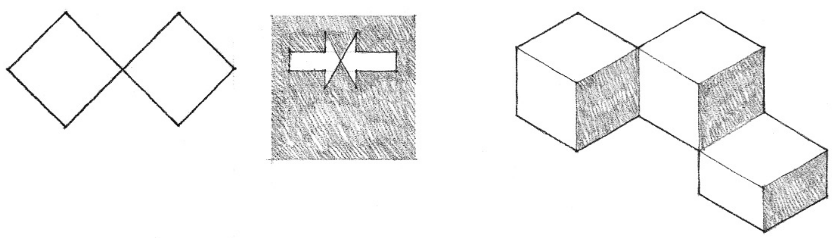


The basic possibilities for grouping two or more forms are described in the following sections.



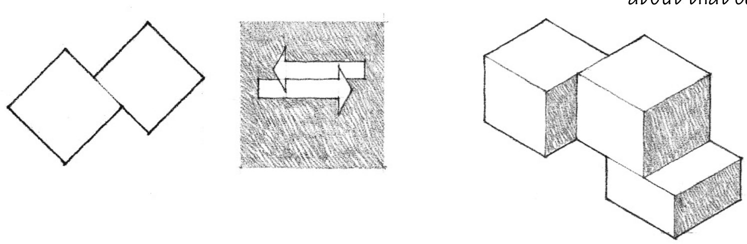
Spatial Tension

This type of relationship relies on the close proximity of the forms or their sharing of a common visual trait, such as shape, color, or material.



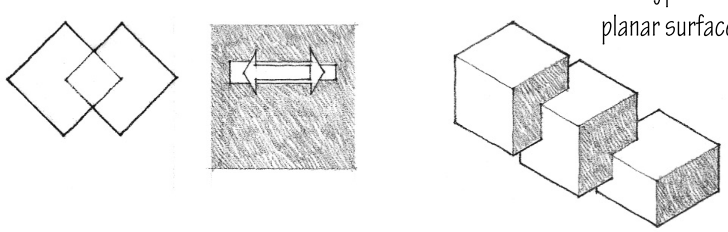
Edge-to-Edge Contact

In this type of relationship, the forms share a common edge and can pivot about that edge.



Face-to-Face Contact

This type of relationship requires that the two forms have corresponding planar surfaces which are parallel to each other.

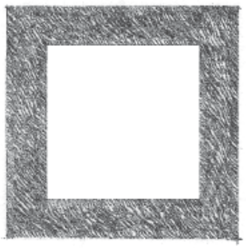


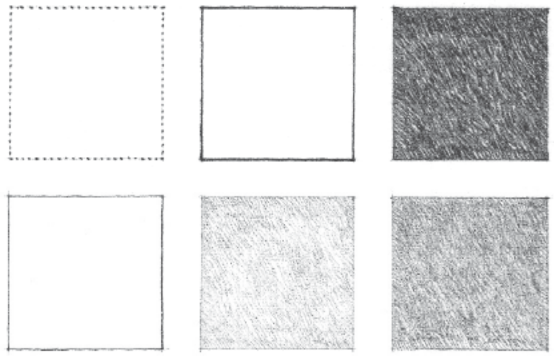
Interlocking Volumes

In this type of relationship, the forms interpenetrate each other's space. The forms need not share any visual traits.

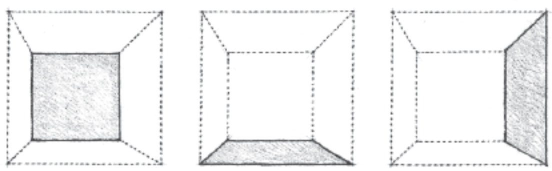
Surface Articulation

Our perception of the shape, size, scale, proportion, and visual weight of a plane is influenced by its surface properties as well as its visual context.

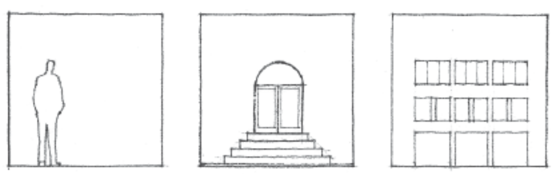




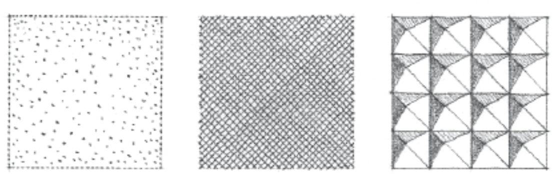
A distinct contrast between the surface color of a plane and that of the surrounding field can clarify its shape, while modifying its tonal value can either increase or decrease its visual weight.



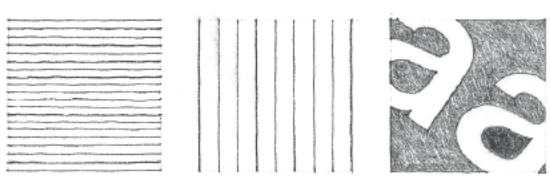
A frontal view reveals the true shape of a plane; oblique views distort it.



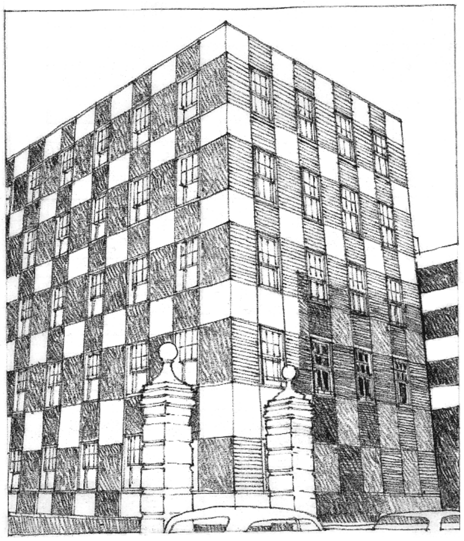
Elements of known size within the visual context of a plane can aid our perception of its size and scale.



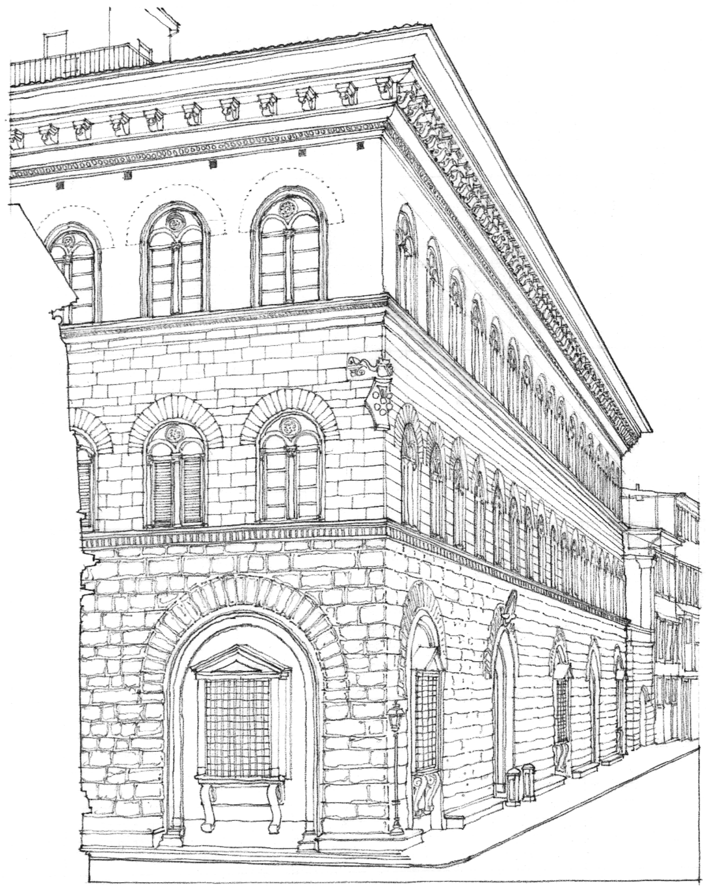
Texture and color together affect the visual weight and scale of a plane and the degree to which it absorbs or reflects light and sound.



Directional or oversized optical patterns can distort the shape or exaggerate the proportions of a plane.

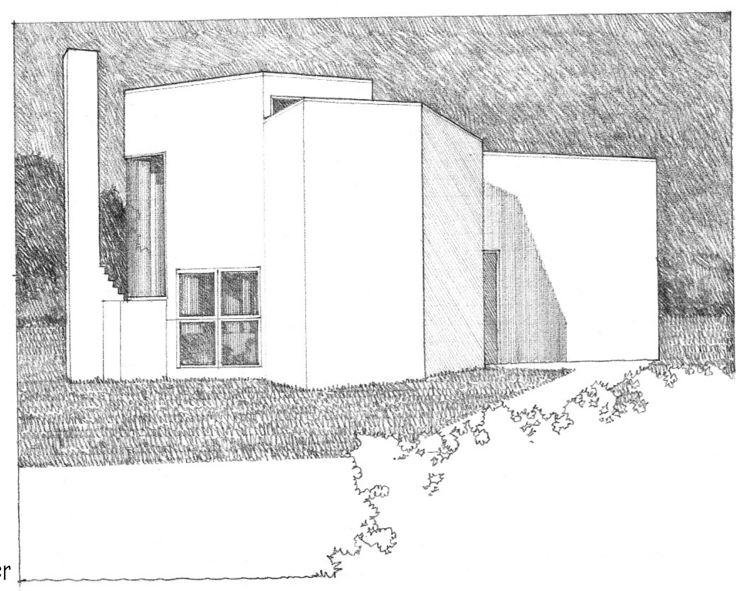


Vincent Street Flats, London, 1928, Sir Edwin Lutyens



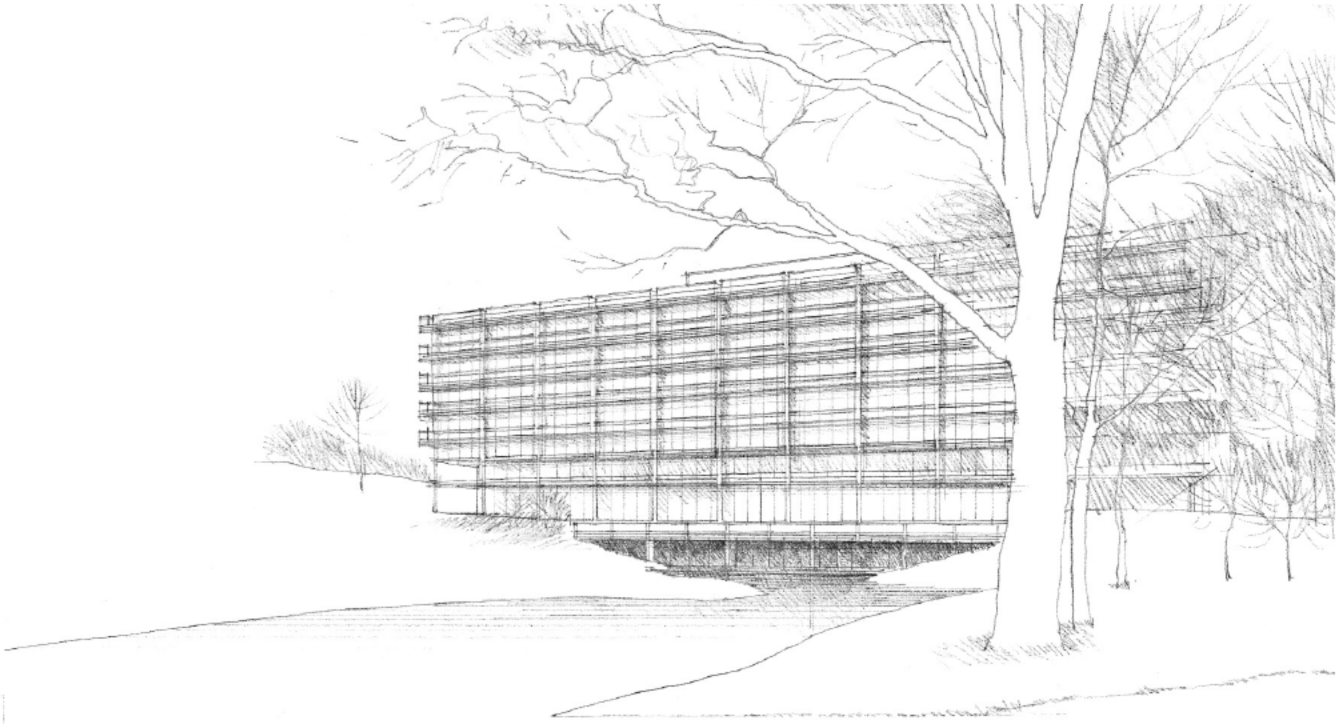
Palazzo Medici-Ricardo, Florence, Italy, 1444–1460, Michelozzi

The color, texture, and pattern of surfaces articulate the existence of planes and influence the visual weight of a form.

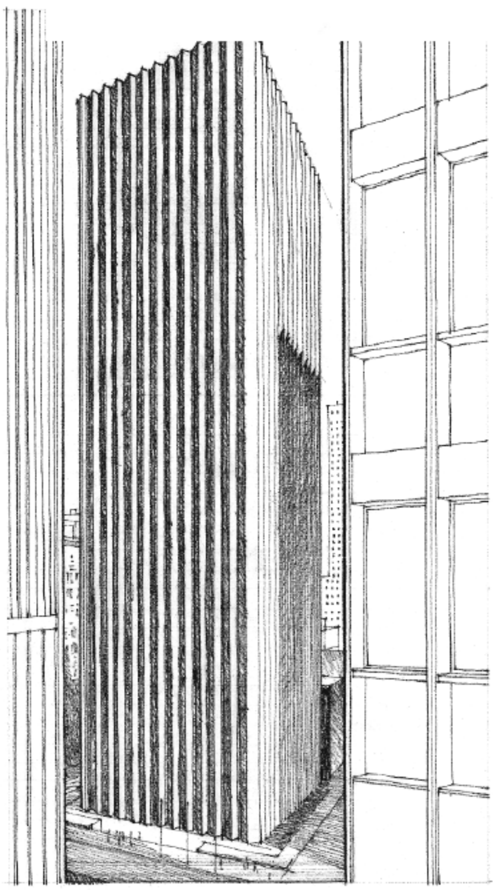


Hoffman House, East Hampton, New York, 1966–1967, Richard Meier

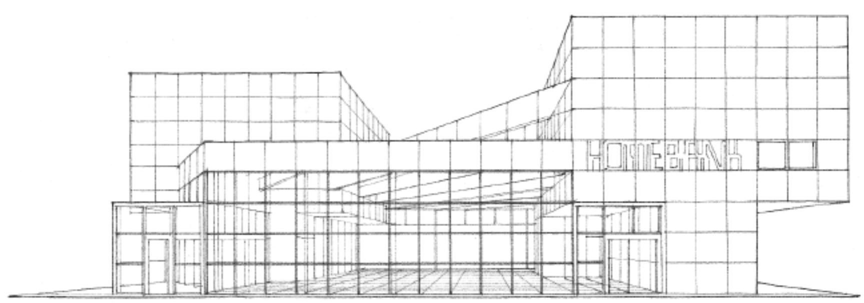
Linear patterns have the ability to emphasize the height or length of a form, unify its surfaces, and define its textural quality.



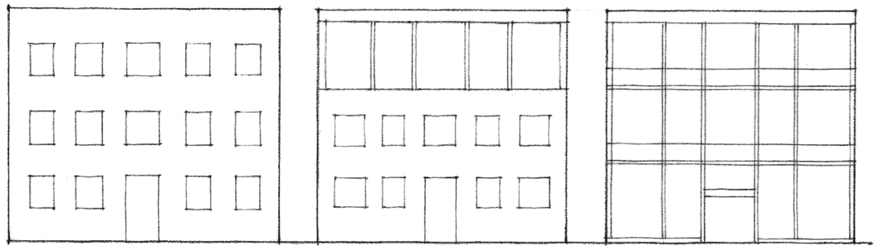
John Deere & Company Building, Moline, Illinois, 1961–1964, Eero Saarinen & Associates. The linear sun-shading devices accentuate the horizontality of the building's form.



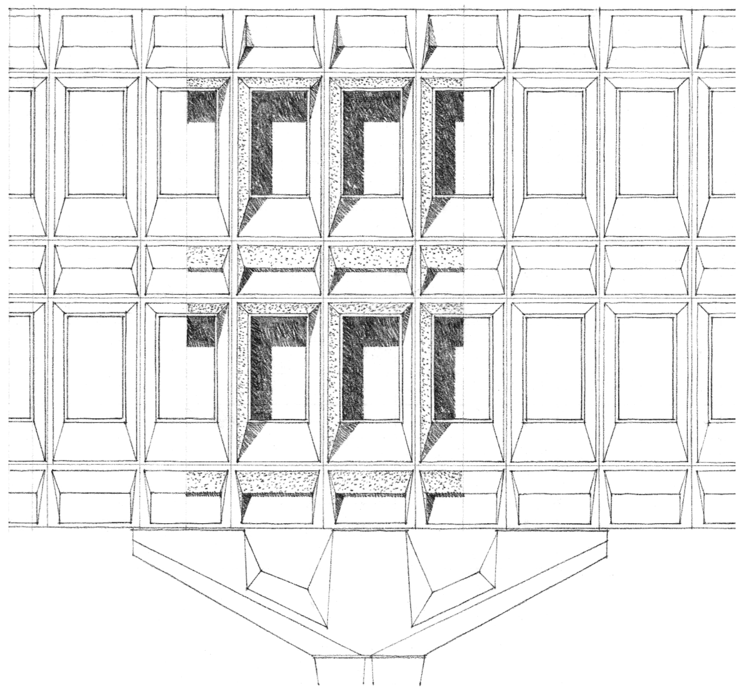
CBS Building, New York City, 1962–1964, Eero Saarinen & Associates. Linear columnar elements emphasize the verticality of this high-rise structure.



Fukuoka Sogo Bank, Study of the Saga Branch, 1971, Arata Isozaki. A grid pattern unifies the surfaces of the three-dimensional composition.

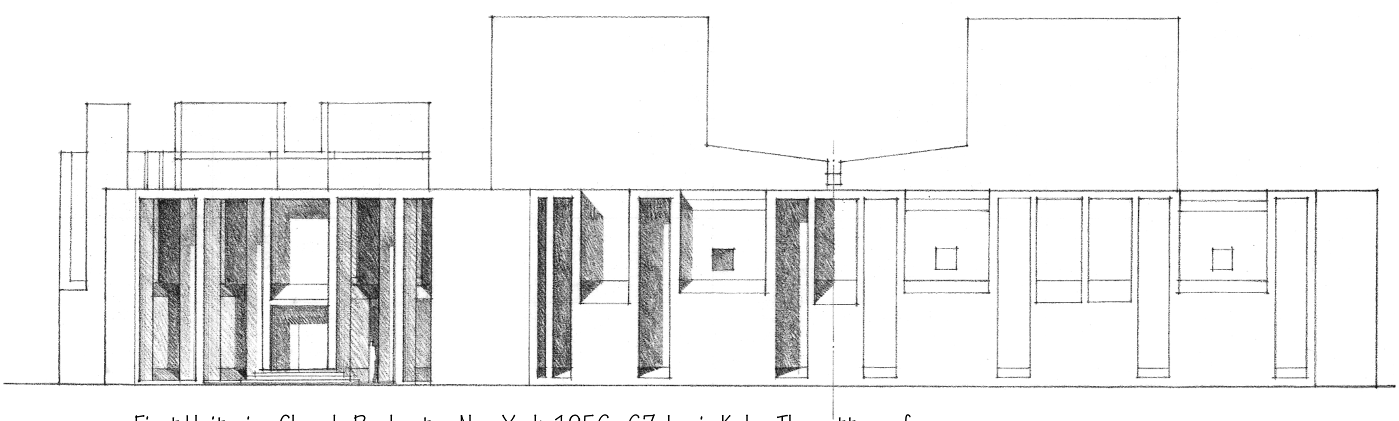


A transformation from a pattern of openings in a plane to an open facade articulated by a linear framework.



Examples of Linear Patterns on Building Form

IBM Research Center, La Guade, Var, France, 1960–1961, Marcel Breuer. The three-dimensional form of the openings creates a texture of light, shade, and shadows.



First Unitarian Church, Rochester, New York, 1956–67, Louis Kahn. The pattern of openings and cavities interrupts the continuity of the exterior wall planes.

Form and Movement

A circulation space may be enclosed, open on one side, or open on both sides.

Enclosed

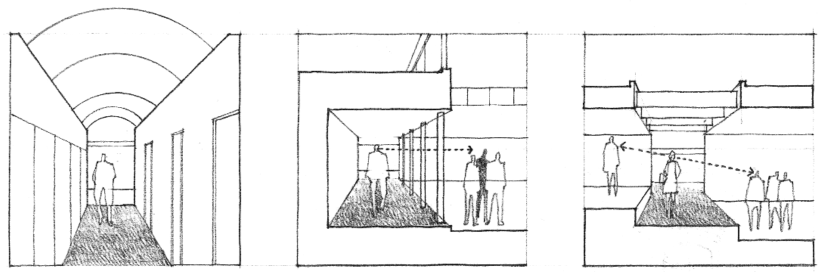
An enclosed space forms a public galleria or private corridor that relates to the spaces it links though entrances in a wall plane.

Open on One Side

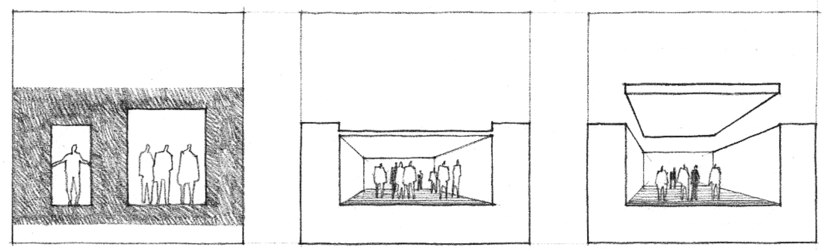
A space open on one side forms a balcony or gallery that provides visual and spatial continuity with the spaces it links.

Open on Both Sides

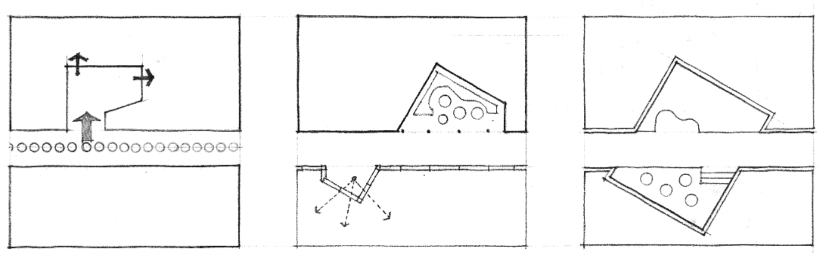
A space open on both sides forms a colonnaded passageway that becomes a physical extension of the space it passes through.



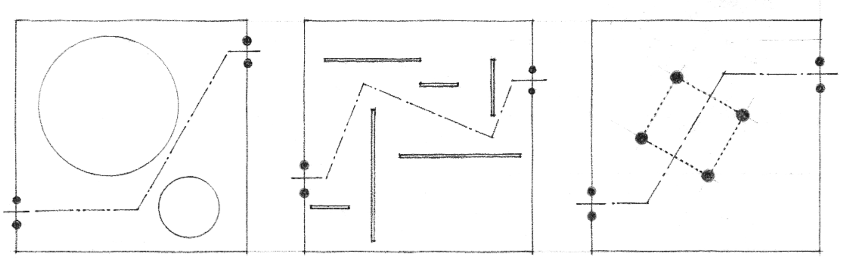
The width and height of a circulation space should be proportionate with the type and amount of movement it must handle. A distinction in scale should be established between a public promenade, a more private hall, and a service corridor.



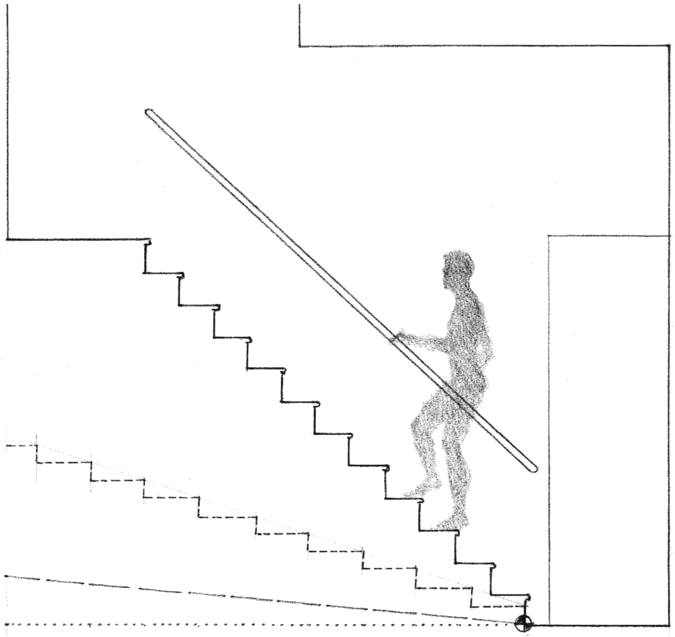
A narrow, enclosed path naturally encourages forward motion. To accommodate more traffic, as well as to create spaces for pausing, resting, or viewing, sections of a path can be widened. The path can also be enlarged by merging it with the spaces it passes through.



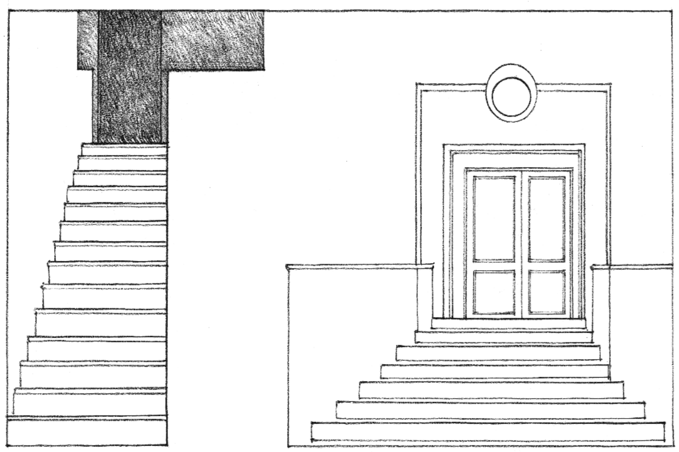
Within a large space, a path can be random, without form or definition, and be determined by the activities and arrangement of furnishings within the space.



Stairs and Stairways

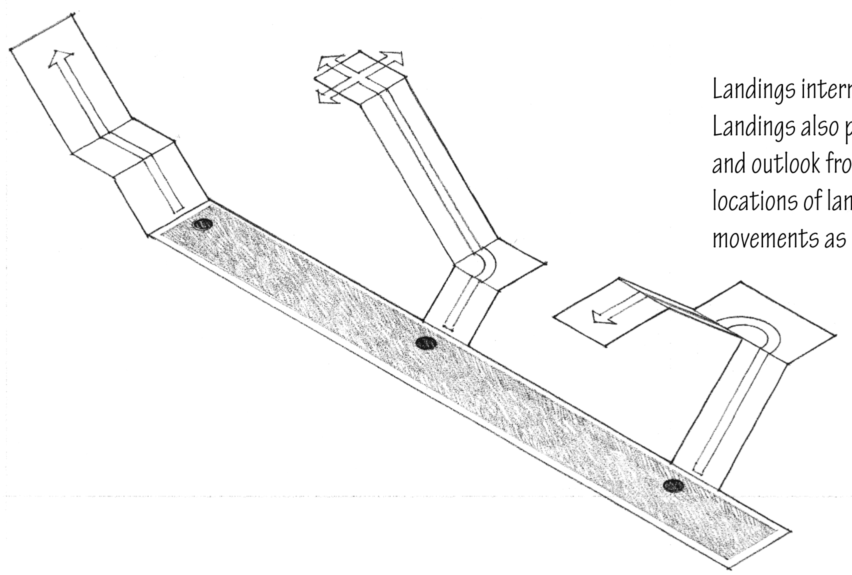


Stairs and stairways provide for vertical movement between the levels of a building or outdoor space. The slope of a stairway, determined by the dimensions of its risers and treads, should be proportioned to fit our body movement and capability. If steep, a stair can make ascent physically tiring as well as psychologically forbidding, and can make descent precarious. If shallow, a stair must have treads deep enough to fit our stride.



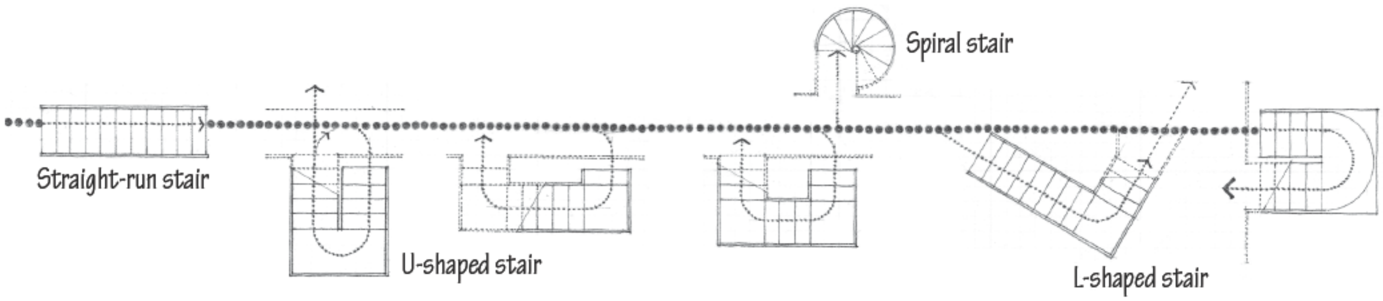
A stairway should be wide enough to comfortably accommodate our passage as well as any furnishings and equipment that must be moved up or down the steps. The width of a stairway also provides a visual clue to the public or private nature of the stairway. Wide, shallow steps can serve as an invitation, while a narrow, steep stairway can lead to more private places.

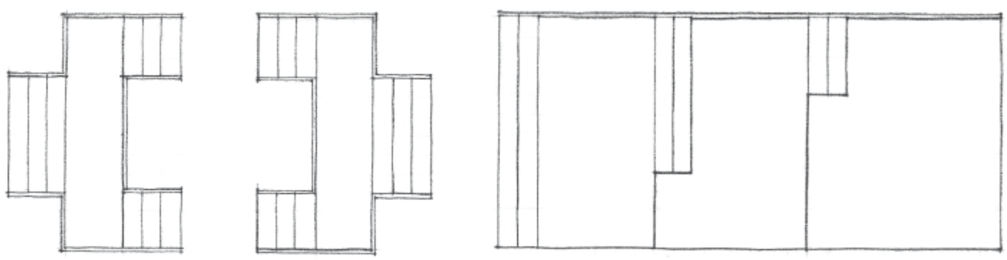
While the act of traversing up a stairway may convey privacy, aloofness, or detachment, the process of going down can imply moving toward secure, protected, or stable ground.

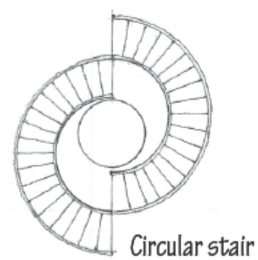


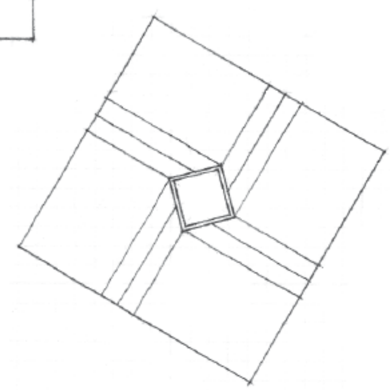
Landings interrupt the run of a stair and enable it to change direction. Landings also provide opportunities for rest and possibilities for access and outlook from the stairway. Together with the pitch of a stair, the locations of landings determine the rhythm and choreography of our movements as we ascend or descend its steps.

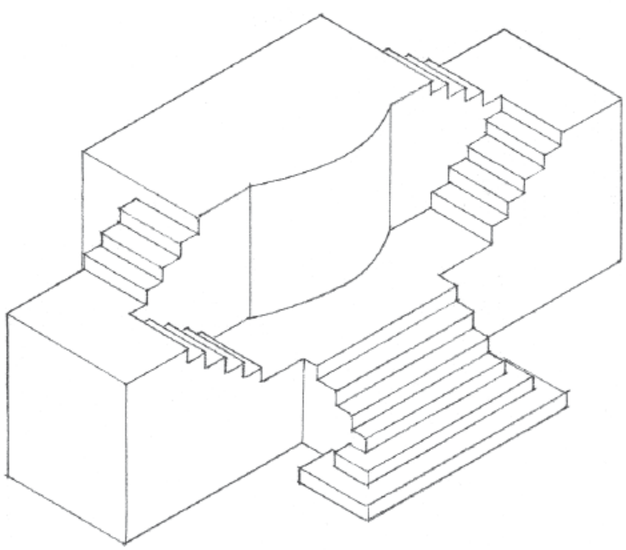
Stairs, in accommodating a change in level, can reinforce the path of movement, interrupt it, accommodate a change in its course, or terminate it prior to entering a major space.







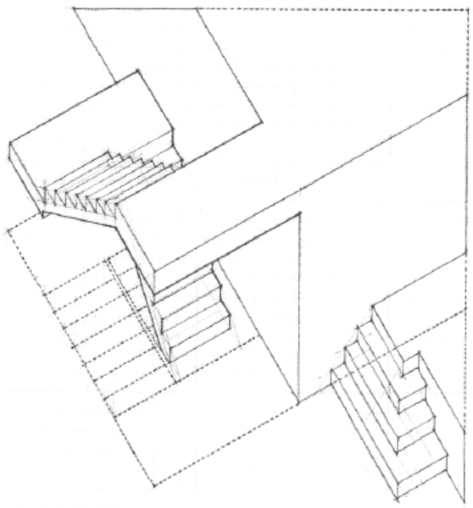


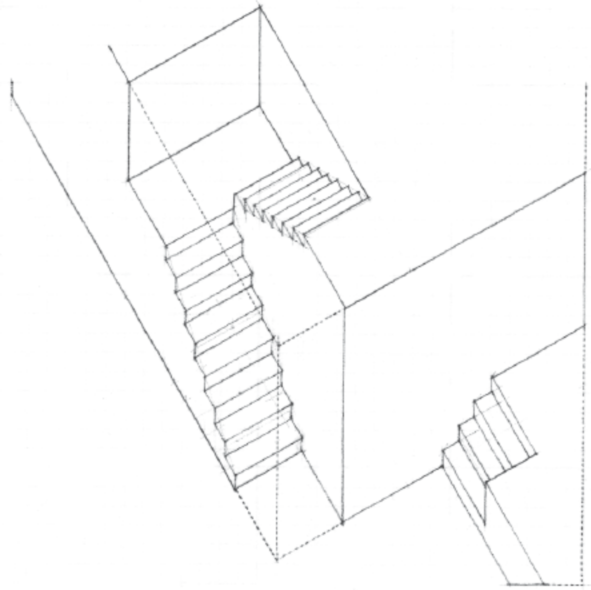


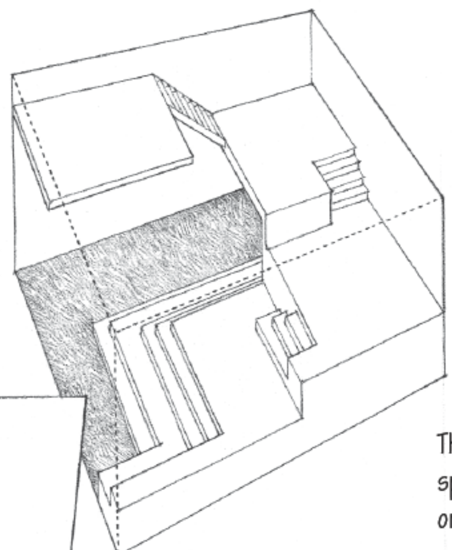
The configuration of a stairway determines the direction of our path as we ascend or descend its steps. There are several basic ways in which to configure the runs of a stairway:

- Straight-run stair
- L-shaped stair
- U-shaped stair
- Circular stair
- Spiral stair

The space a stairway occupies can be great, but its form can be fitted into an interior in several ways. It can be treated as an additive form or as a volumetric solid from which space has been carved out for movement as well as rest.



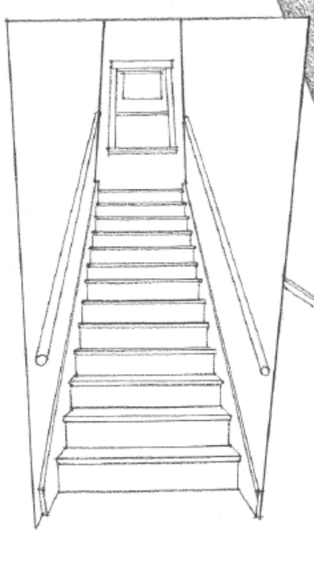


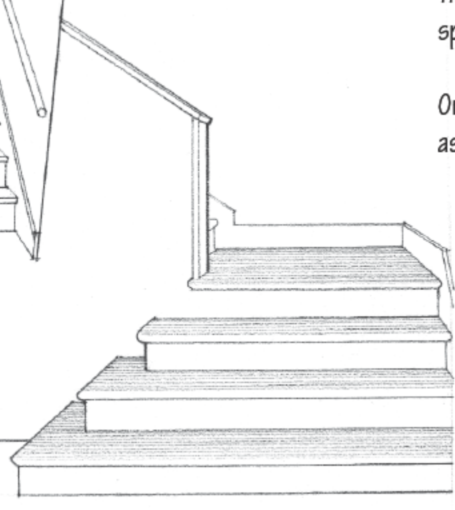


The stairway can run along one of the edges of a room, wrap around the space, or fill its volume. It can be woven into the boundaries of a space or be extended into a series of platforms for seating or terraces for activity.

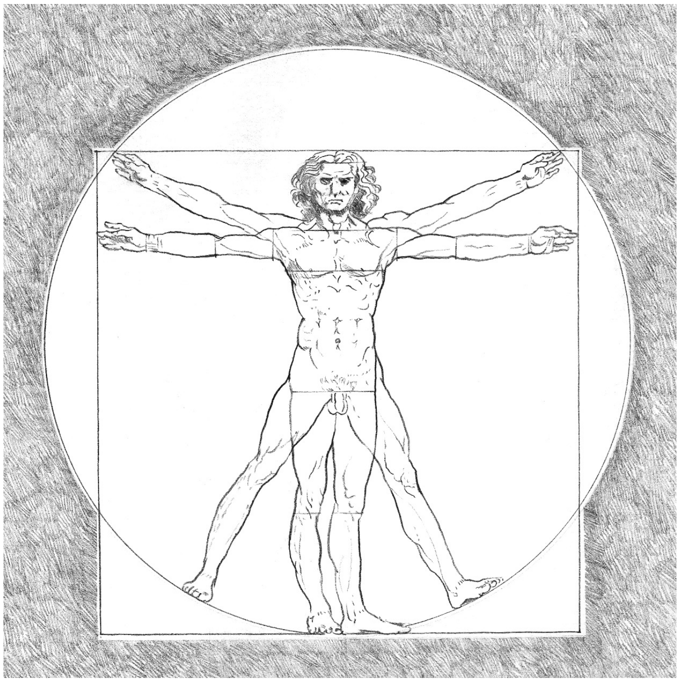
The path of a stair can rise between walls through a narrow shaft of space to offer access to a private place or signify unapproachability.

On the other hand, landings which are visible on approach invite ascent, as do treads which spillout at the bottom of a stairway.

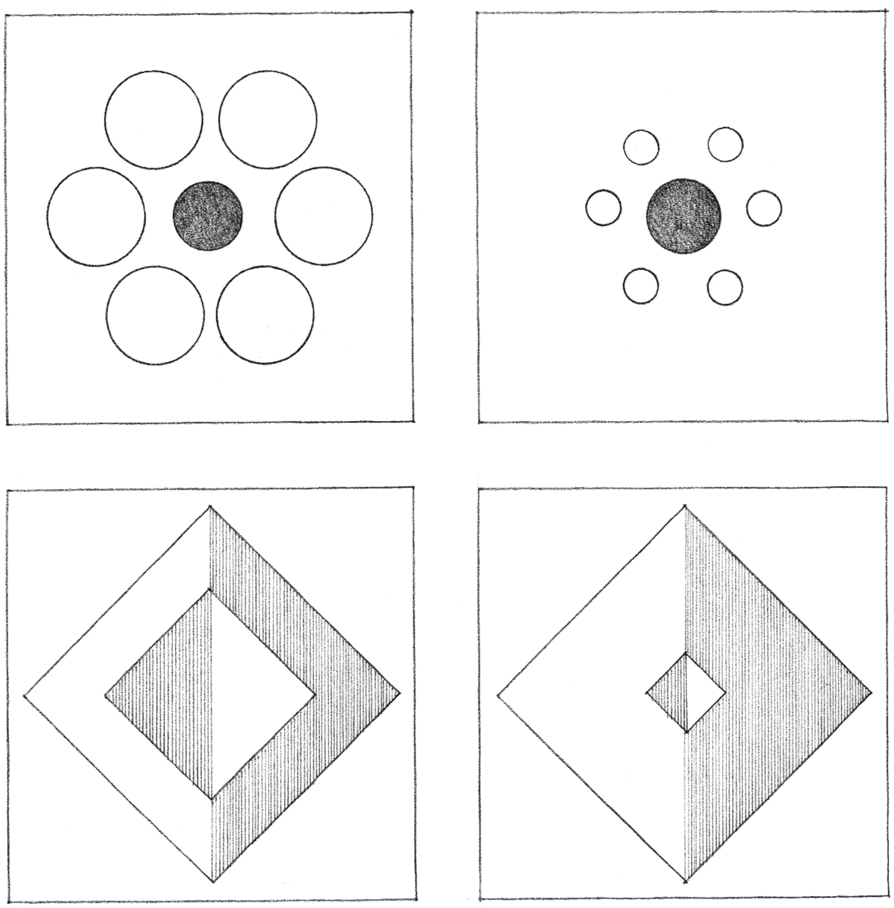


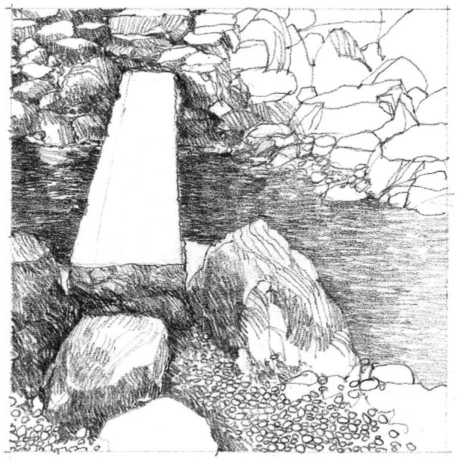


Proportion and Scale



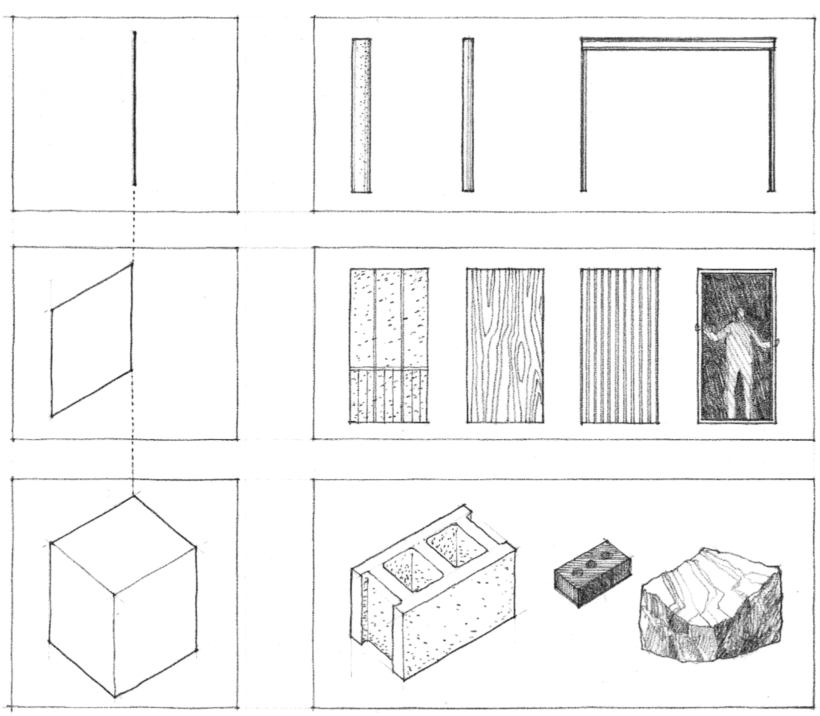
While scale alludes to the size of something compared to a reference standard or to the size of something else, proportion refers to the proper or harmonious relation of one part to another or to the whole. This relationship may not only be one of magnitude, but also of quantity or degree. While the designer usually has a range of choices when determining the proportions of things, some are given to us by the nature of materials, by how building elements respond to forces, and by how things are made.

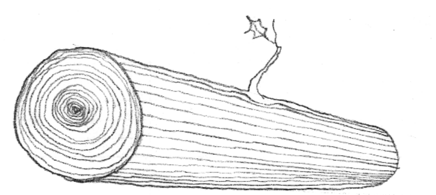


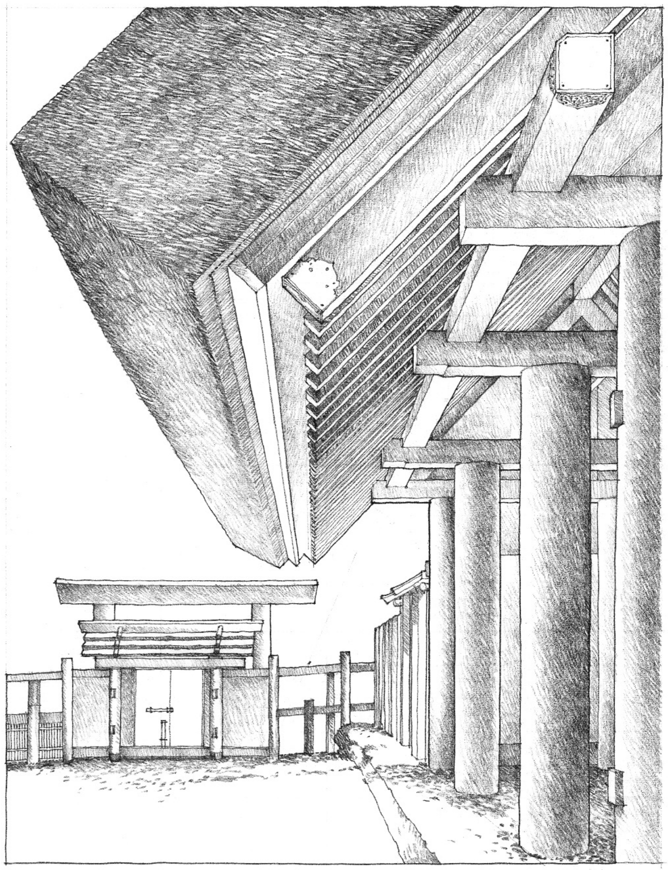


All building materials in architecture have distinct properties of elasticity, hardness, and durability. They also all have an ultimate strength beyond which they cannot extend themselves without fracturing, breaking, or collapsing. Since the stresses in a material resulting from the force of gravity increase with size, all materials also have rational dimensions beyond which they cannot go. For example, a stone slab that is 4 inches thick and 8 feet long can be reasonably expected to support itself as a bridge between two supports. If, however, its size were to increase fourfold, to 16 inches thick and 32 feet long, it would probably collapse under its own weight. Even a strong material like steel has lengths beyond which it cannot span without exceeding its ultimate strength.

All materials also have rational proportions, which are dictated by their inherent strengths and weaknesses. Masonry units like brick, for example, are strong in compression and depend on their mass for strength. Such materials are, therefore, volumetric in form. Materials like steel are strong in both compression and tension and can, therefore, be formed into linear columns and beams as well as planar sheet materials. Wood, being a flexible and fairly elastic material, can be used as linear posts and beams, as planar boards, and as a volumetric element in log cabin construction.





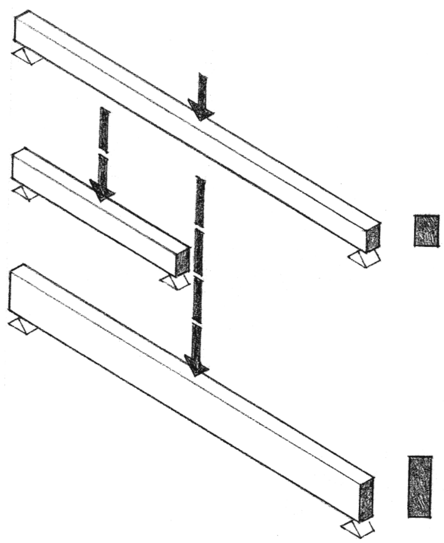


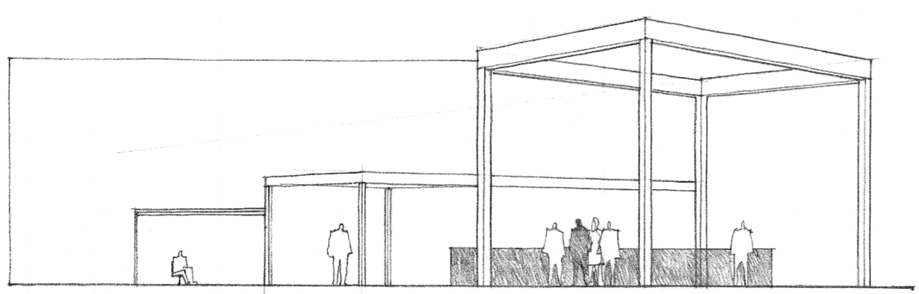
South gateway of the third fence of Naigu, the inner shrine, Ise Shrine, Mie Prefecture, Japan, 690 CE

In the construction of architecture, structural elements are called upon to span spaces and transmit their loads through vertical supports to the foundation system of a building. The size and proportion of these elements are directly related to the structural tasks they perform and can, therefore, be visual indicators of the size and scale of the spaces they help enclose.

Beams, for example, transmit their loads horizontally across space to their vertical supports. If the span or load of a beam were doubled, its bending stresses would likewise double, possibly causing it to collapse. If, however, its depth were doubled, its strength would increase fourfold. Depth, therefore, is the critical dimension of a beam, and its depth-to-span ratio can be a useful indicator of its structural role.

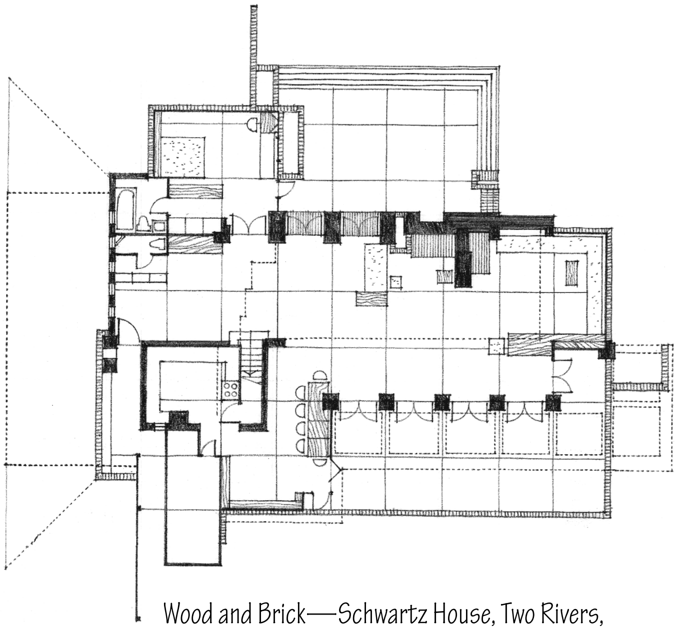
In a similar manner, columns become thicker as their loads and unsupported height increase. Together, beams and columns form a skeletal structural framework that defines modules of space. By their size and proportion, columns and beams articulate space and give it scale and a hierarchical structure. This can be seen in the way joists are supported by beams, which in turn are supported by girders. Each element increases in depth as its load and span increase in size.



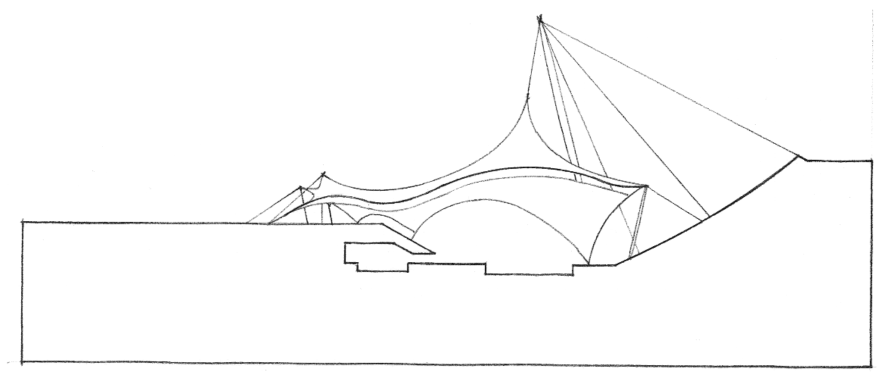


The proportions of other structural elements, such as bearing walls, floor and roof slabs, vaults, and domes, also give us visual clues to their role in a structural system as well as the nature of their material. A masonry wall, being strong in compression but relatively weak in bending, will be thicker than a reinforced concrete wall doing the same work. A steel column will be thinner than a wood post supporting the same load. A 4-inch-thick reinforced concrete slab will span farther than 4-inch wood decking.

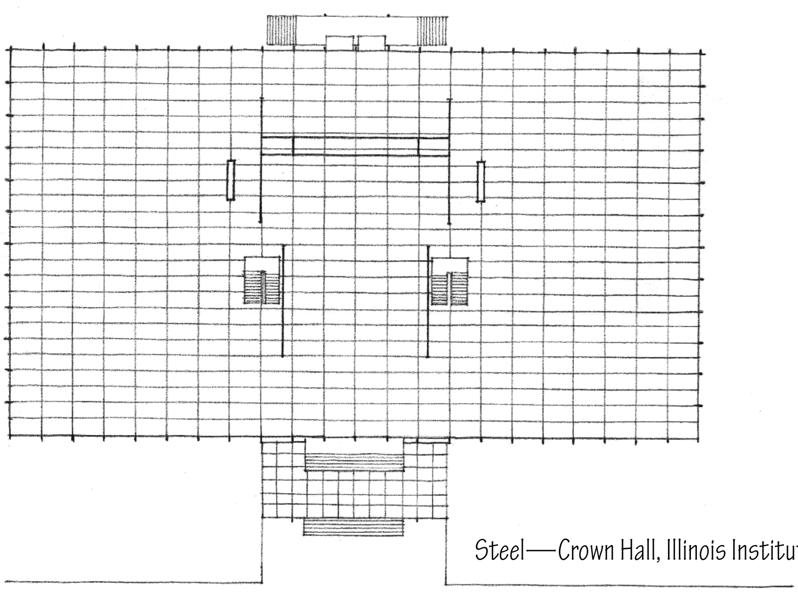
As a structure depends less on the weight and stiffness of a material and more on its geometry for stability, as in the case of a membrane structure or a space frame, its elements will get thinner and thinner until they lose their ability to give a space scale and dimension.



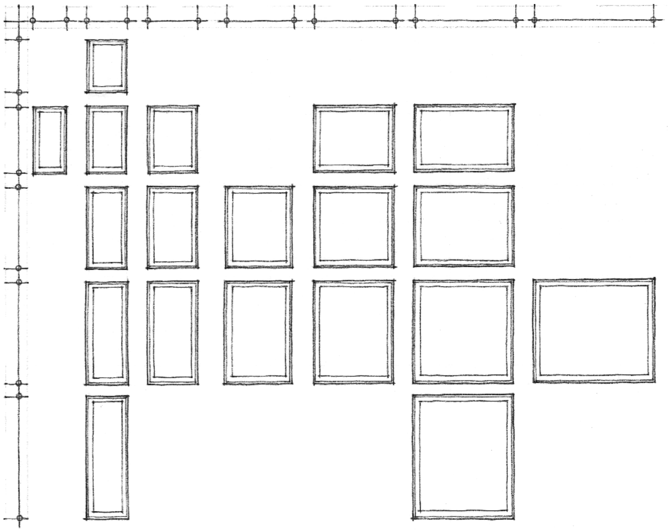
Wood and Brick—Schwartz House, Two Rivers, Wisconsin, 1939, Frank Lloyd Wright



Membrane—Roof of Olympic Swimming Arena, Munich, Germany, 1972, Frei Otto



Steel—Crown Hall, Illinois Institute of Technology, Chicago, 1956, Mies van der Rohe

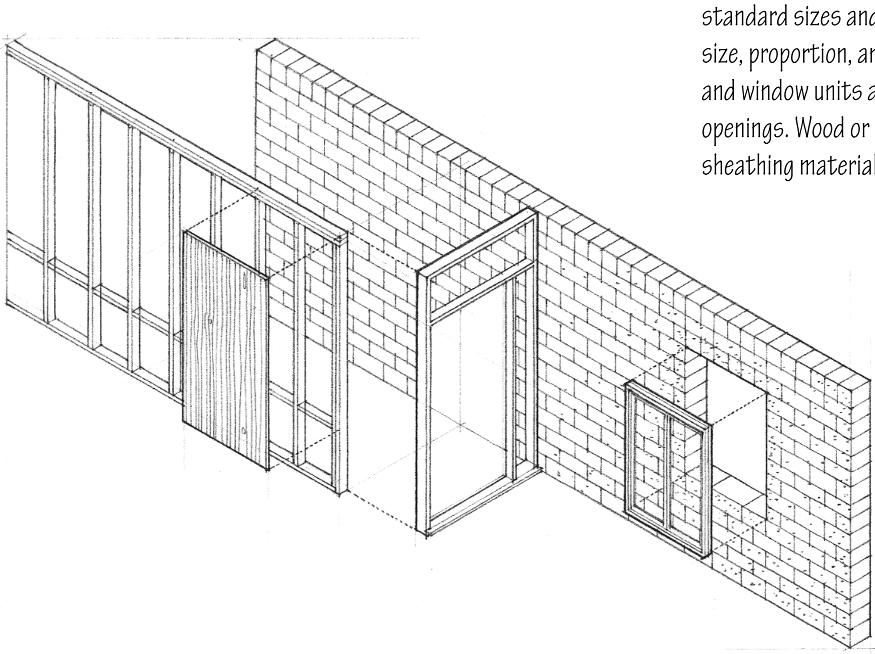


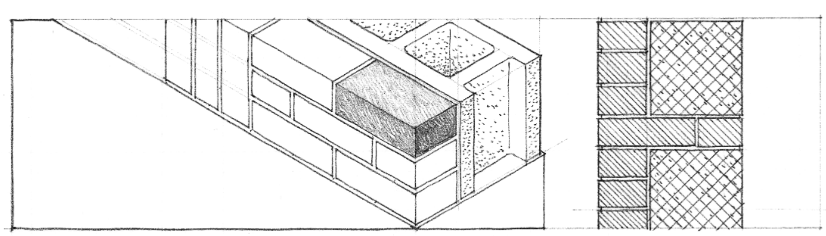
Standard casement window units

Many architectural elements are sized and proportioned not only according to their structural properties and function, but also by the process through which they are manufactured. Because these elements are mass-produced in factories, they have standard sizes and proportions imposed on them by the individual manufacturers or by industry standards.

Concrete block and common brick, for example, are produced as modular building units. Although they differ from each other in size, both are proportioned on a similar basis. Plywood and other sheathing materials also are manufactured as modular units with fixed proportions. Steel sections have fixed proportions generally agreed upon by the steel manufacturers and the American Institute of Steel Construction. Windows and doors have proportions that are set by the individual manufacturers of the units.

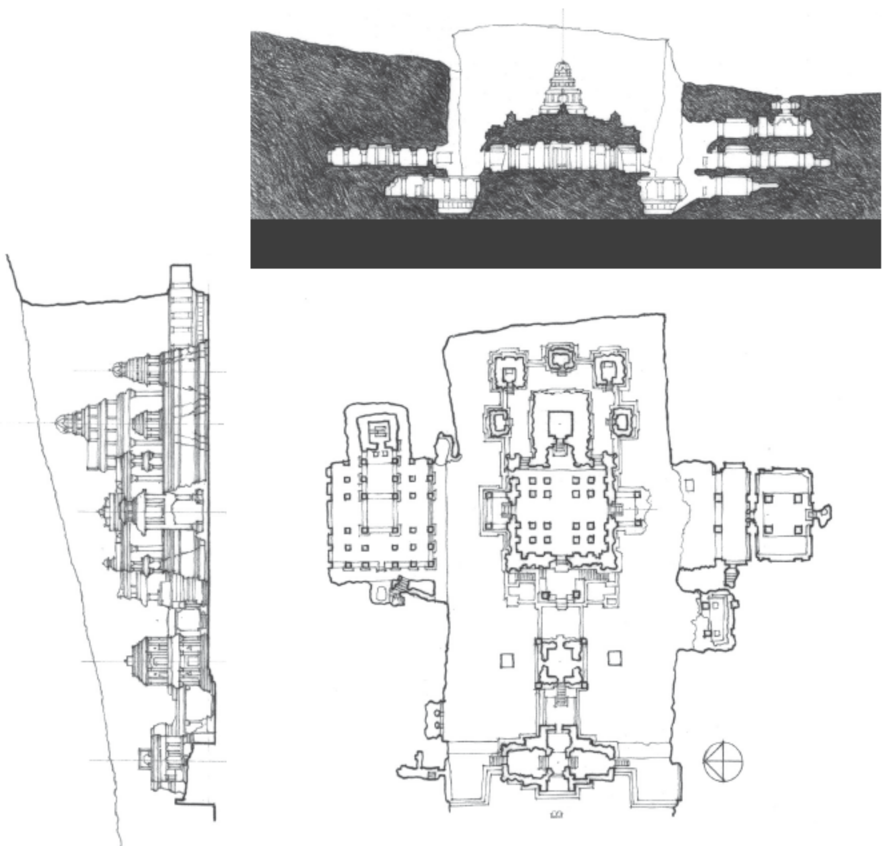
Since these and other materials must ultimately come together and achieve a high degree of fit in the construction of a building, the standard sizes and proportions of factory-produced elements affect the size, proportion, and spacing of other materials as well. Standard door and window units are sized and proportioned to fit into modular masonry openings. Wood or metal studs and joists are spaced to accept modular sheathing materials.





5 Fundamentals of Architecture:

Space



Temple of Kailasnath at Ellora, near Aurangabad, India, 600–1000 CE

Why Is Space Important in Architecture?

Space is the void between forms. It is the primary medium of architecture because space can be inhabited. In architecture space is also carefully configured to house various functions—it provides purpose to a building. This describes the program of architecture, and it is the responsibility of the architect to configure spaces to accommodate the functions of a building.

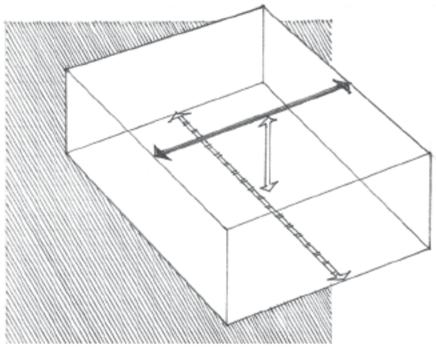
This happens in several ways through the design process. The function of a space is facilitated by variables that can be manipulated by the architect:

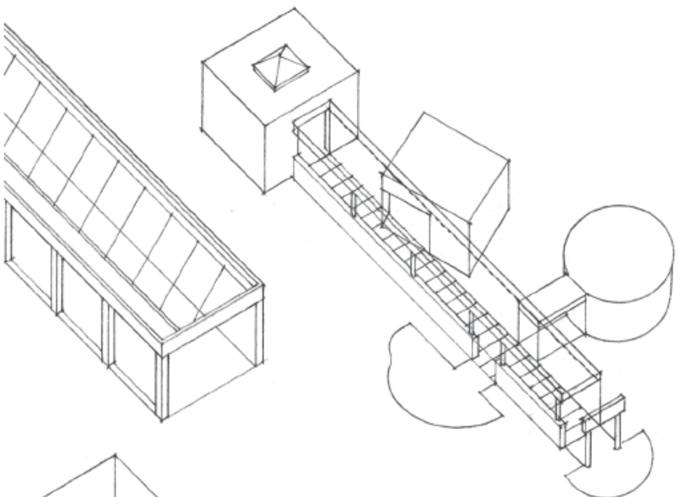
- The size and proportion of a space determine the functions it can and cannot house.

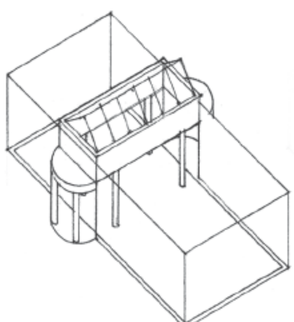
- Its organization relative to other spaces in a building determines the degree of access and relationships to other functions in the building.

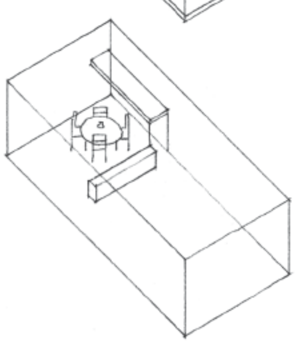
- Materials, proportion, light, and temperature determine the way the space is perceived and can be used to encourage an occupant to behave in one way or another.

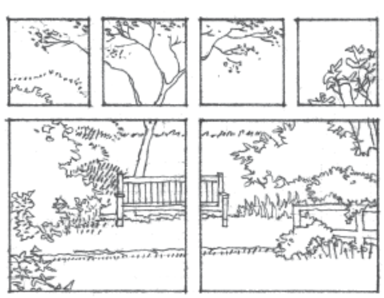
Architecture is an environment that is experienced by its inhabitants. The architect manufactures this experience. It is a direct result of design. Although space is the primary medium of architecture, it is also defined and contained by form. So, it is form that is manipulated in order to determine its organizational, programmatic, and experiential characteristics. This chapter discusses the many subtle ways in which space and form can be configured toward a particular function or experience. It addresses the variables that can be manipulated by the architect and the consequences of those decisions.

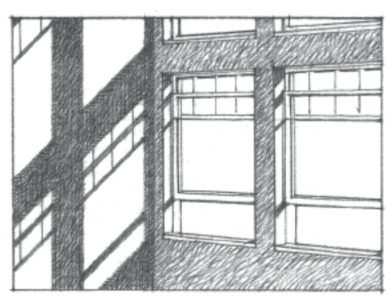




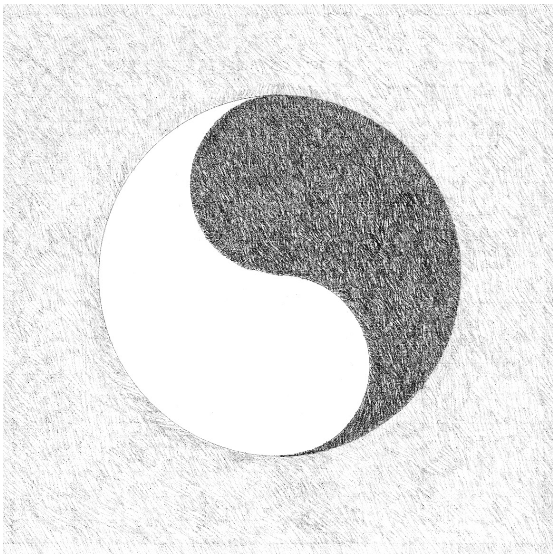




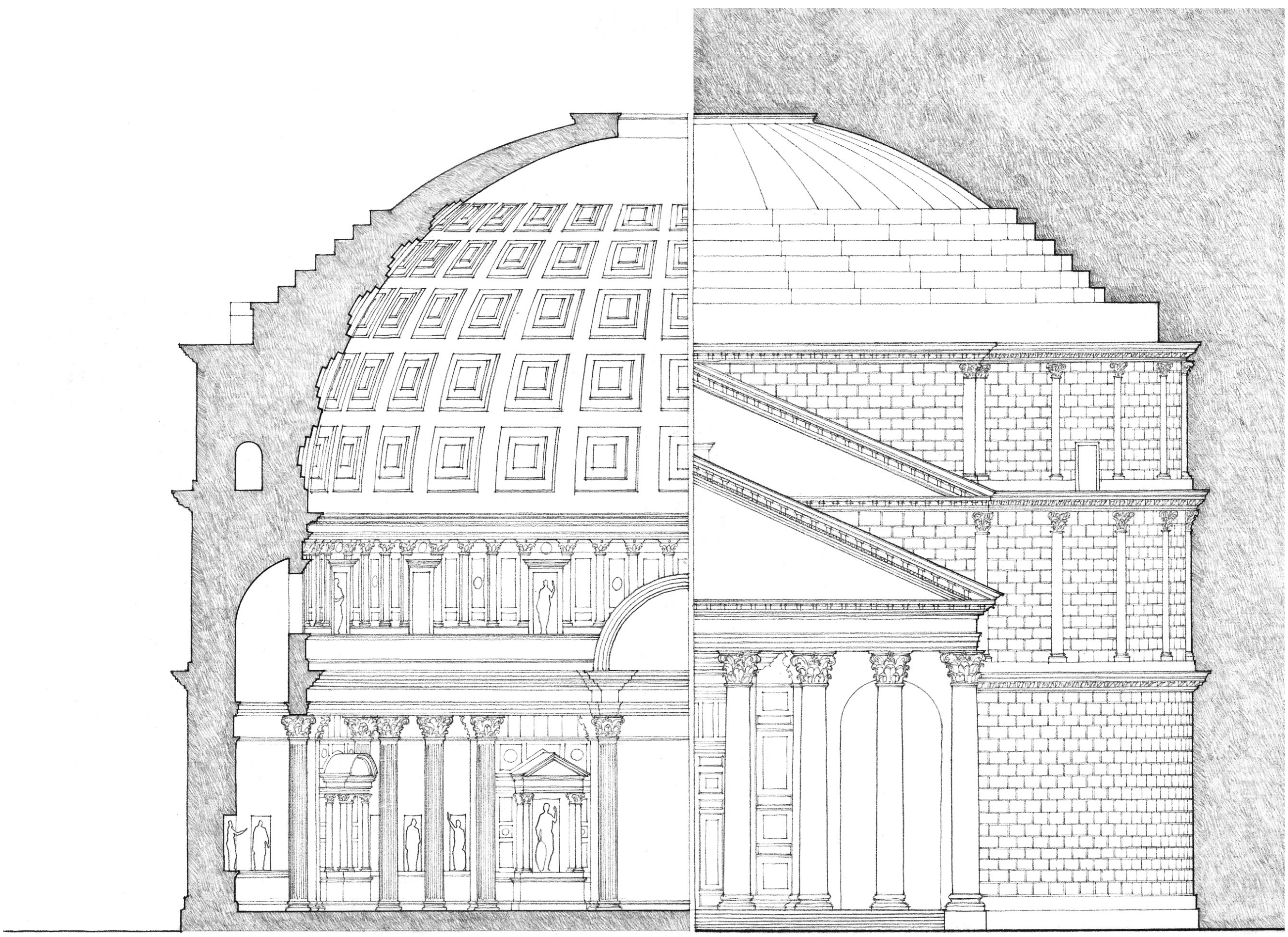




Form and Space

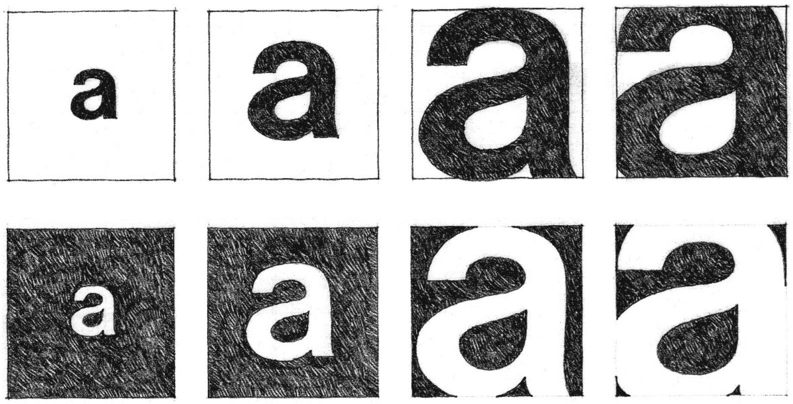


Space constantly encompasses our being. Through the volume of space, we move, see forms, hear sounds, feel breezes, and smell the fragrances of a flower garden in bloom. It is a material substance like wood or stone. Yet it is an inherently formless vapor. Its visual form, its dimensions and scale, the quality of its light—all of these qualities depend on our perception of the spatial boundaries defined by elements of form. As space begins to be captured, enclosed, molded, and organized by the elements of mass, architecture comes into being.



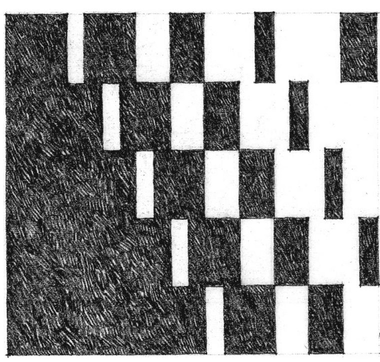
The Pantheon, Rome, 120–124 CE

Unity of Opposites

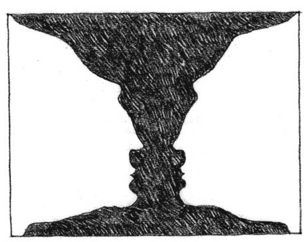


Our visual field normally consists of heterogeneous elements that differ in shape, size, color, or orientation. To better comprehend the structure of a visual field, we tend to organize its elements into two opposing groups: positive elements, which are perceived as figures, and negative elements, which provide a background for the figures.

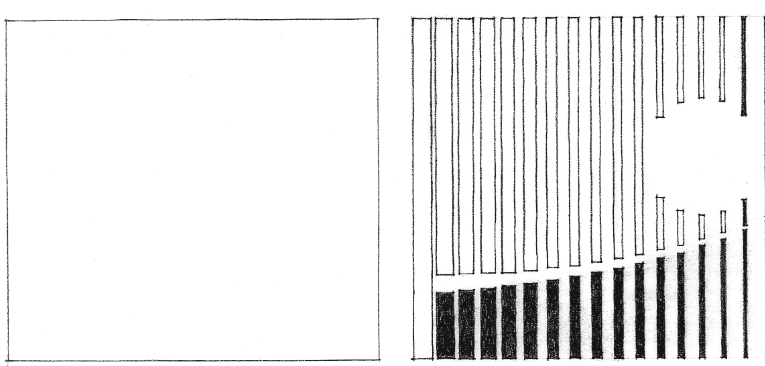
Our perception and understanding of a composition depends on how we interpret the visual interaction between the positive and negative elements within its field. On this page, for example, letters are seen as dark figures against the white background of the paper's surface. Consequently, we are able to perceive their organization into words, sentences, and paragraphs. In the upper left figures, the letter "a" is seen as a figure not only because we recognize it as a letter in our alphabet but also because its profile is distinct, its value contrasts with that of its background, and its placement isolates it from its context. As it grows in size relative to its field, however, other elements within and around it begin to compete for our attention as figures. At times, the relationship between figures and their background is so ambiguous that we visually switch their identities back and forth almost simultaneously.



White-on-black or black-on-white?

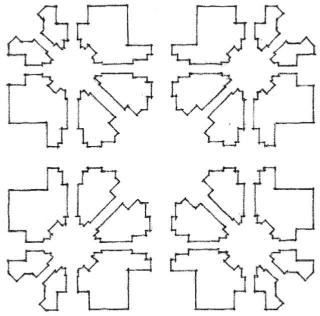


Two faces or a vase?

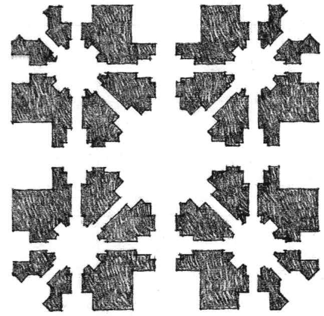


In all cases, however, we should understand that figures, the positive elements that attract our attention, could not exist without a contrasting background. Figures and their background, therefore, are more than opposing elements. Together, they form an inseparable reality—a unity of opposites—just as the elements of form and space together form the reality of architecture.

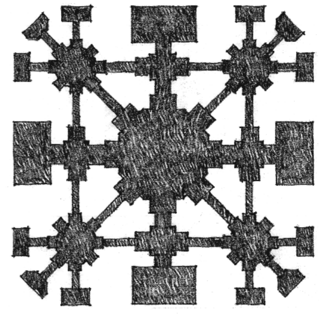
Taj Mahal, Agra, India, 1630–1653. Shah Jahan built this white marble mausoleum for his favorite wife, Muntaz Mahal.



Line defining the boundary between solid mass and spatial void



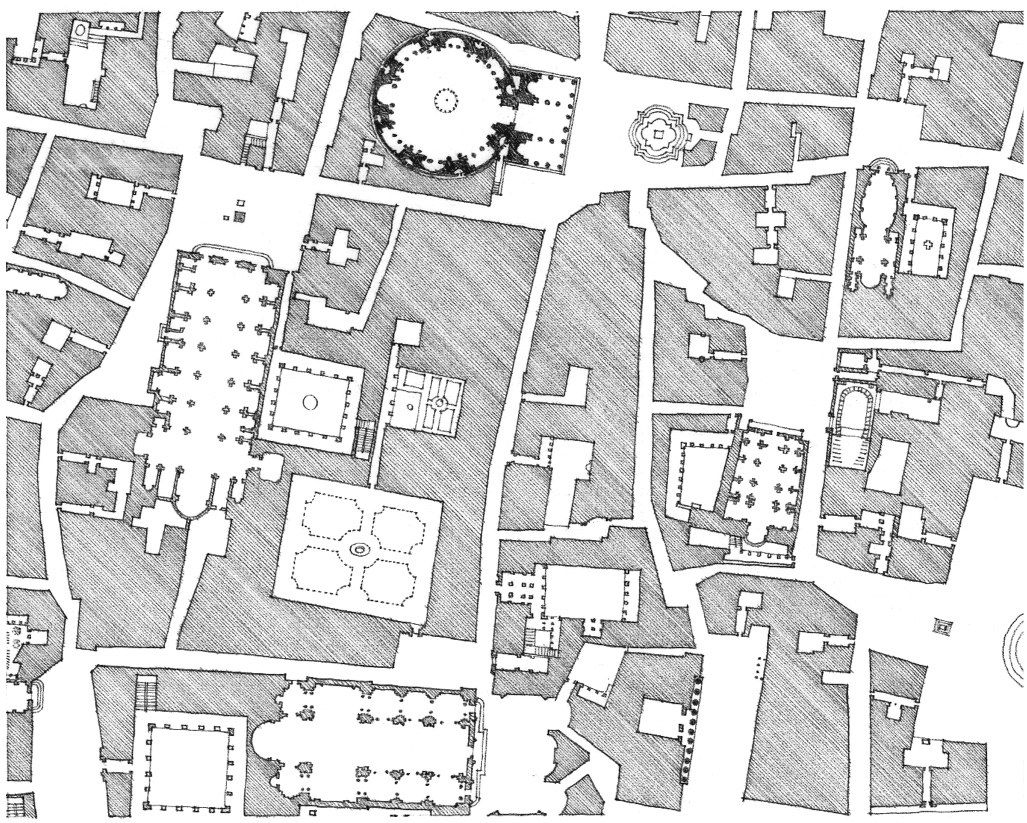
The form of solid mass rendered as a figure



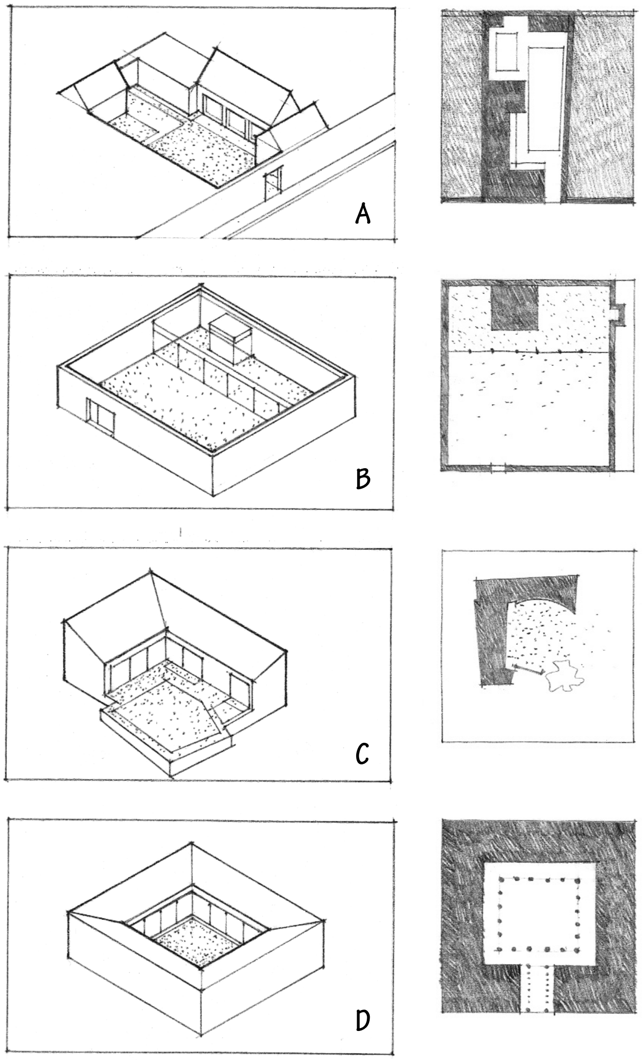
The form of the spatial void rendered as figure

Architectural form occurs at the juncture between mass and space. In executing and reading design drawings, we should be concerned with both the form of the mass containing a volume of space and the form of the spatial volume itself.

Fragment of a map of Rome, drawn by Giambattista Nolli in 1748



Depending on what we perceive to be positive elements, the figure-ground relationship of the forms of mass and space can be inverted in different parts of this map of Rome. In portions of the map, buildings appear to be positive forms that define street spaces. In other parts of the drawing, urban squares, courtyards, and major spaces within important public buildings read as positive elements seen against the background of the surrounding building mass.



The symbiotic relationship of the forms of mass and space in architecture can be examined and found to exist at several different scales. At each level, we should be concerned not only with the form of a building but also with its impact on the space around it. At an urban scale, we should carefully consider whether the role of a building is to continue the existing fabric of a place, form a backdrop for other buildings, or define a positive urban space, or whether it might be appropriate for it to stand free as a significant object in space.

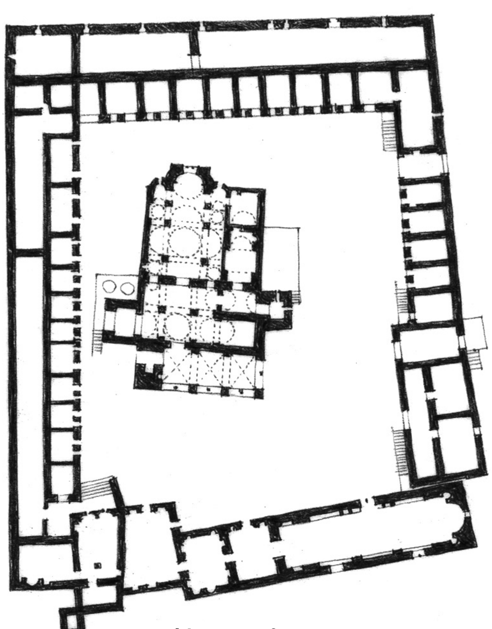
At the scale of a building site, there are various strategies for relating the form of a building to the space around it. A building can

A. form a wall along an edge of its site and begin to define a positive outdoor space;

B. merge its interior space with the private outdoor space of a walled site;

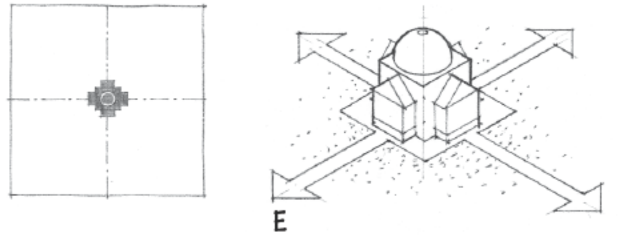
C. enclose a portion of its site as an outdoor room and shelter it from undesirable climatic conditions;

D. surround and enclose a courtyard or atrium space within its volume— an introverted scheme.

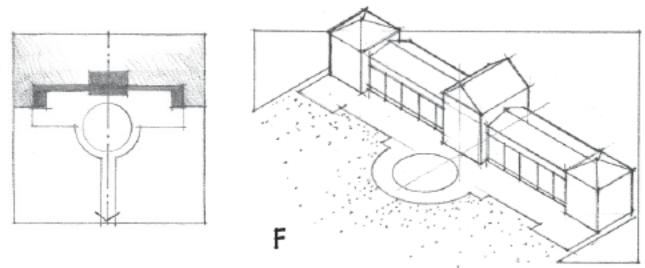


Buildings Defining Space
Monastery of St. Meletios on Mt. Kithairon, *Greece*, ninth century CE

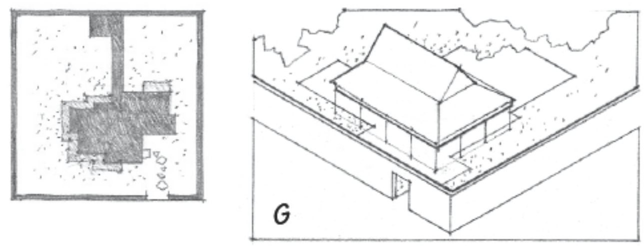
E. stand as a distinct object in space and dominate its site through its form and topographical positioning—an extroverted scheme;



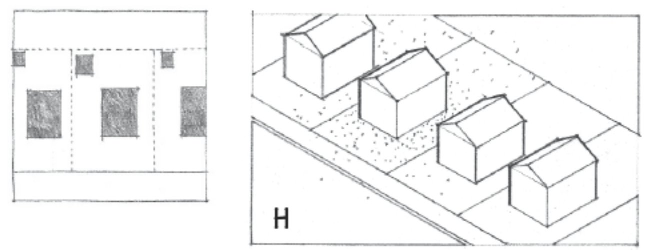
F. stretch out and present a broad face to address a view, terminate an axis, or define an edge of an urban space;

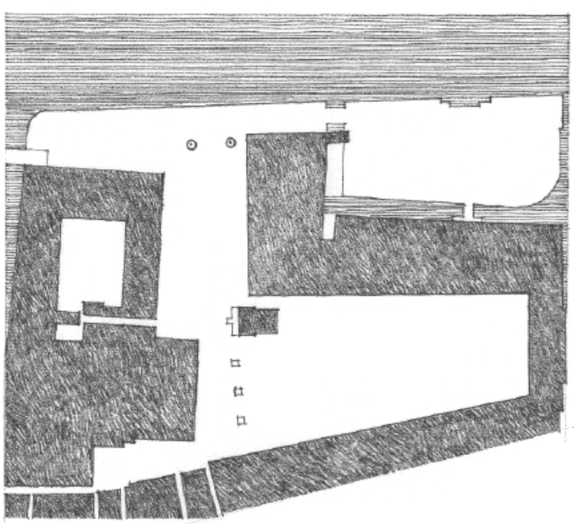


G. stand free within its site but extend its interior spaces to merge with private exterior spaces;

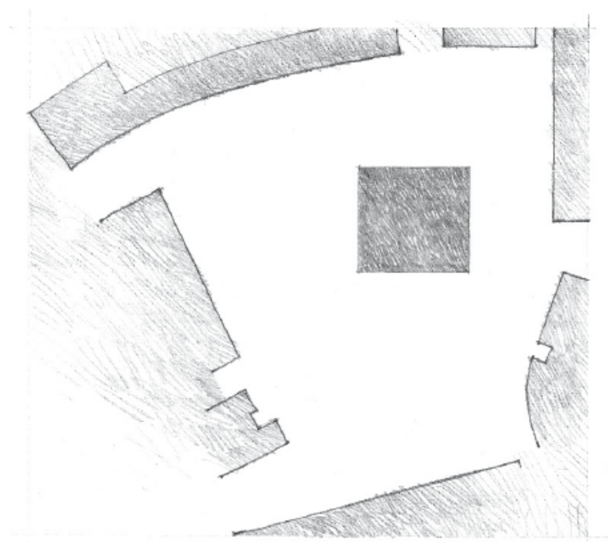


H. stand as a positive form in negative space.



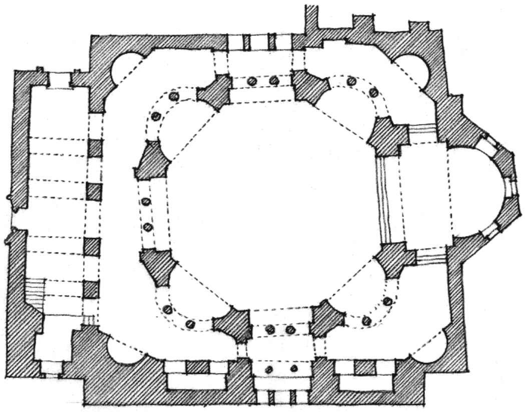


Buildings Defining Space
Piazza of San Marco, Venice

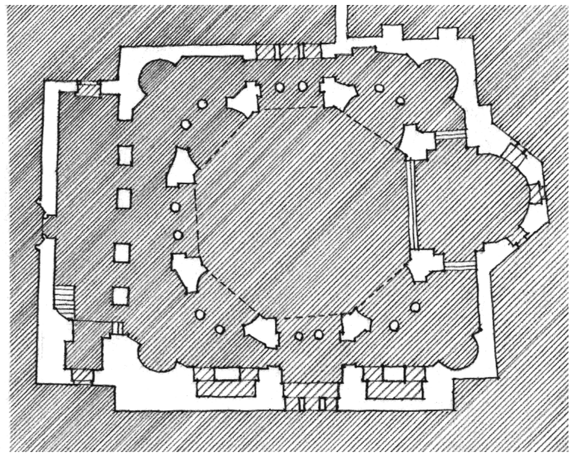


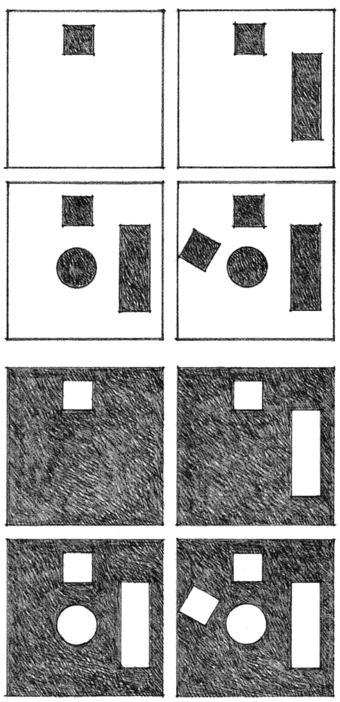
Building as an Object in Space
Boston City Hall, 1960, Kallmann, McKinnell & Knowles

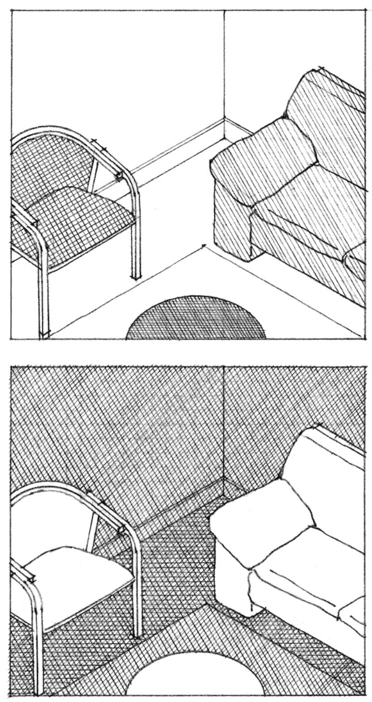
At the scale of a building, we tend to read the configurations of walls as the positive elements of a plan. The white space in between, however, should not be seen simply as background for the walls, but also as figures in the drawing that have shape and form.



S.S. Sergius and Bacchus, Istanbul, 525–530 CE







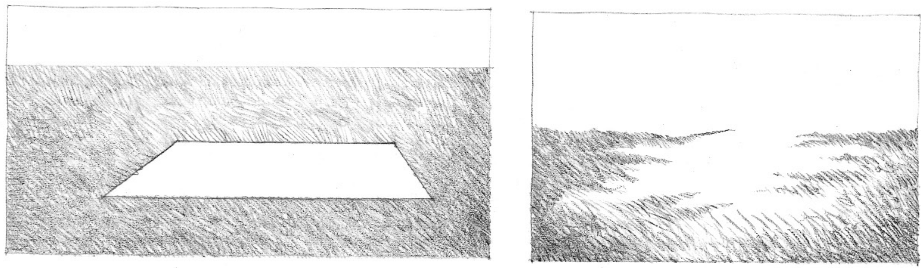
Even at the scale of a room, articles of furnishings can either stand as forms within a field of space or serve to define the form of a spatial field.

Form-Defining Space

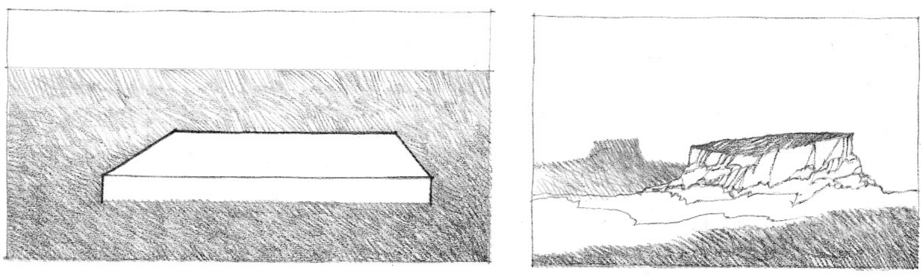
When we place a two-dimensional figure on a piece of paper, it influences the shape of the white space around it. In a similar manner, any three-dimensional form naturally articulates the volume of space surrounding it and generates a field of influence or territory, which it claims as its own. The following section looks at horizontal and vertical elements of form and presents examples of how various configurations of these formal elements generate and define specific types of space.

Square in Giron, Colombia, South America

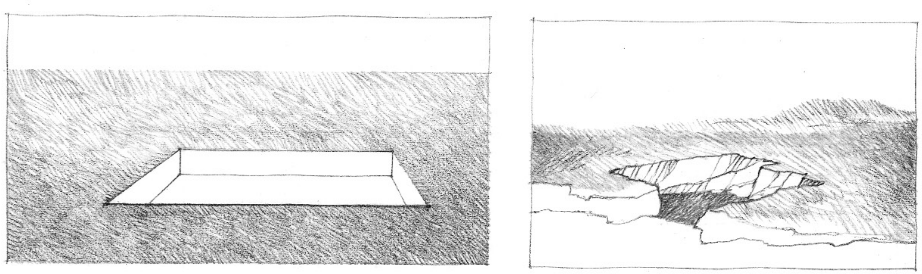
Horizontal Elements Defining Space



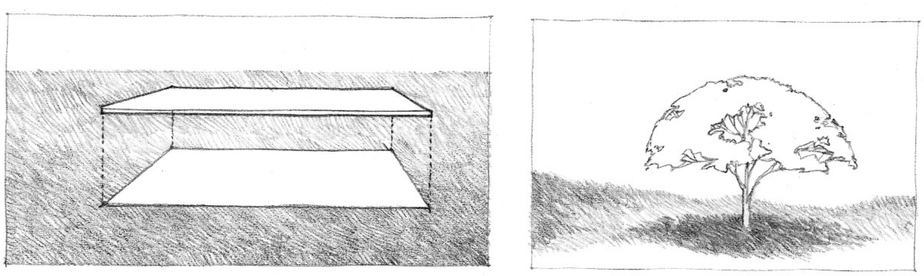
Base Plane
A horizontal plane lying as a figure on a contrasting background defines a simple field of space. This field can be visually reinforced in the following ways.



Elevated Base Plane
A horizontal plane elevated above the ground plane establishes vertical surfaces along its edges that reinforce the visual separation between its field and the surrounding ground.



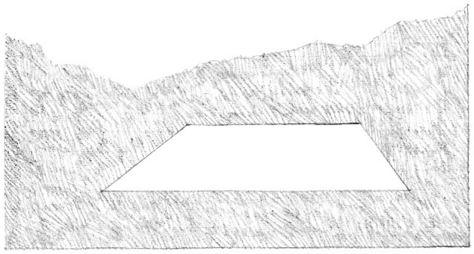
Depressed Base Plane
A horizontal plane depressed into the ground plane uses the vertical surfaces of the lowered area to define a volume of space.

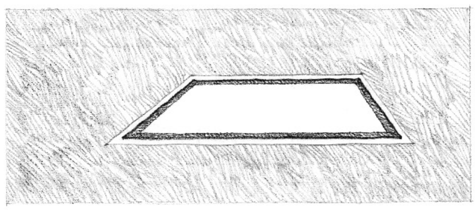


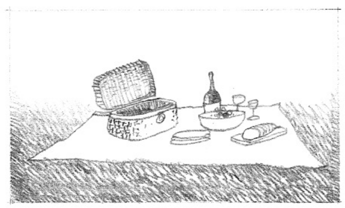
Overhead Plane
A horizontal plane located overhead defines a volume of space between itself and the ground plane.

Base Plane

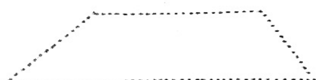
For a horizontal plane to be seen as a figure, there must be a perceptible change in color, tone, or texture between its surface and that of the surrounding area.

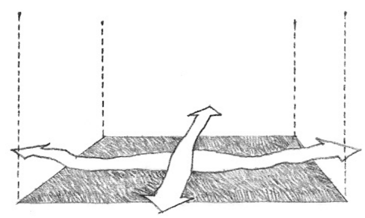




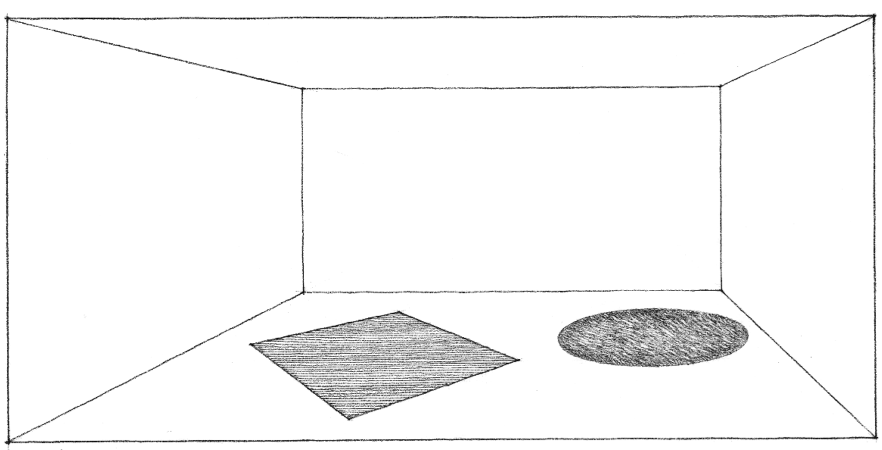


The stronger the edge definition of a horizontal plane is, the more distinct will be its field.





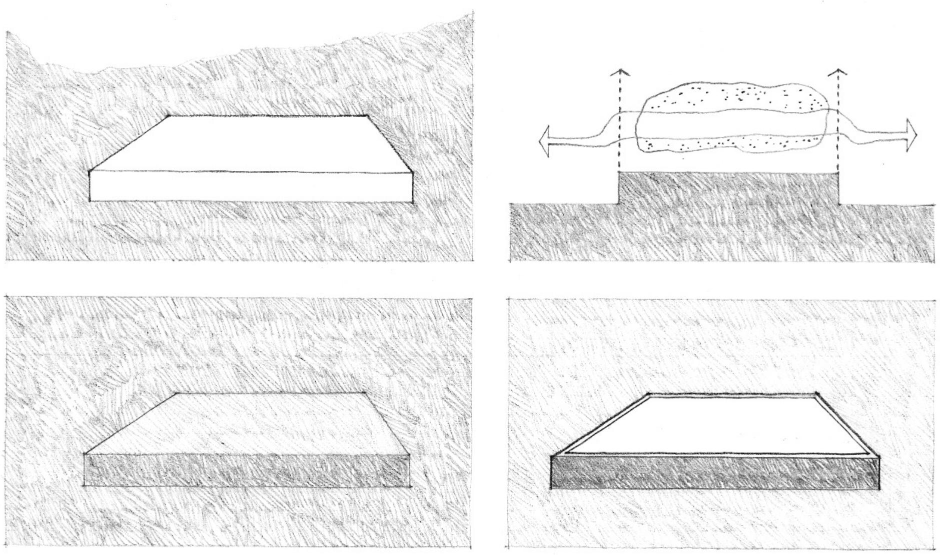
Although there is a continuous flow of space across it, the field nevertheless generates a spatial zone or realm within its boundaries.



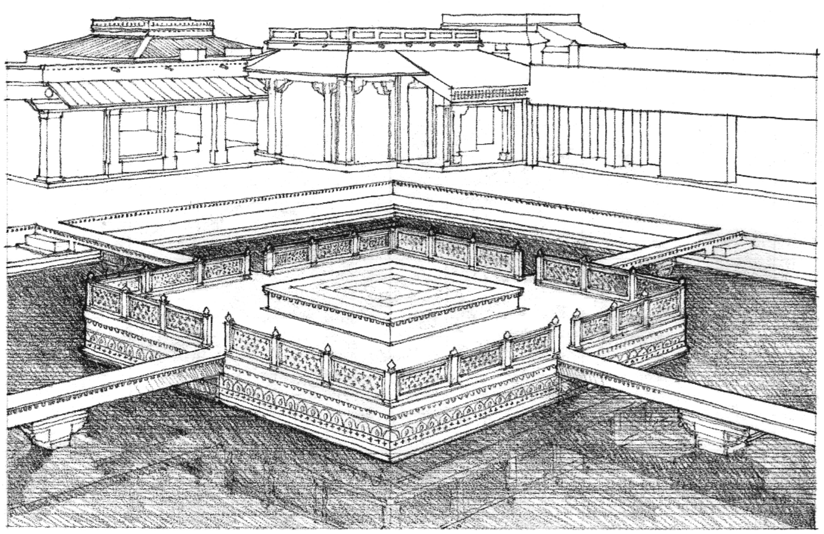
The surface articulation of the ground or floor plane is often used in architecture to define a zone of space within a larger context. This type of spatial definition can be used to differentiate between a path of movement and places of rest, establish a field from which the form of a building rises out of the ground, or articulate a functional zone within a one-room living environment.

Elevated Base Plane

Elevating a portion of the base plane creates a specific domain within a larger spatial context. The changes in level that occur along the edges of the elevated plane define the boundaries of its field and interrupt the flow of space across its surface.



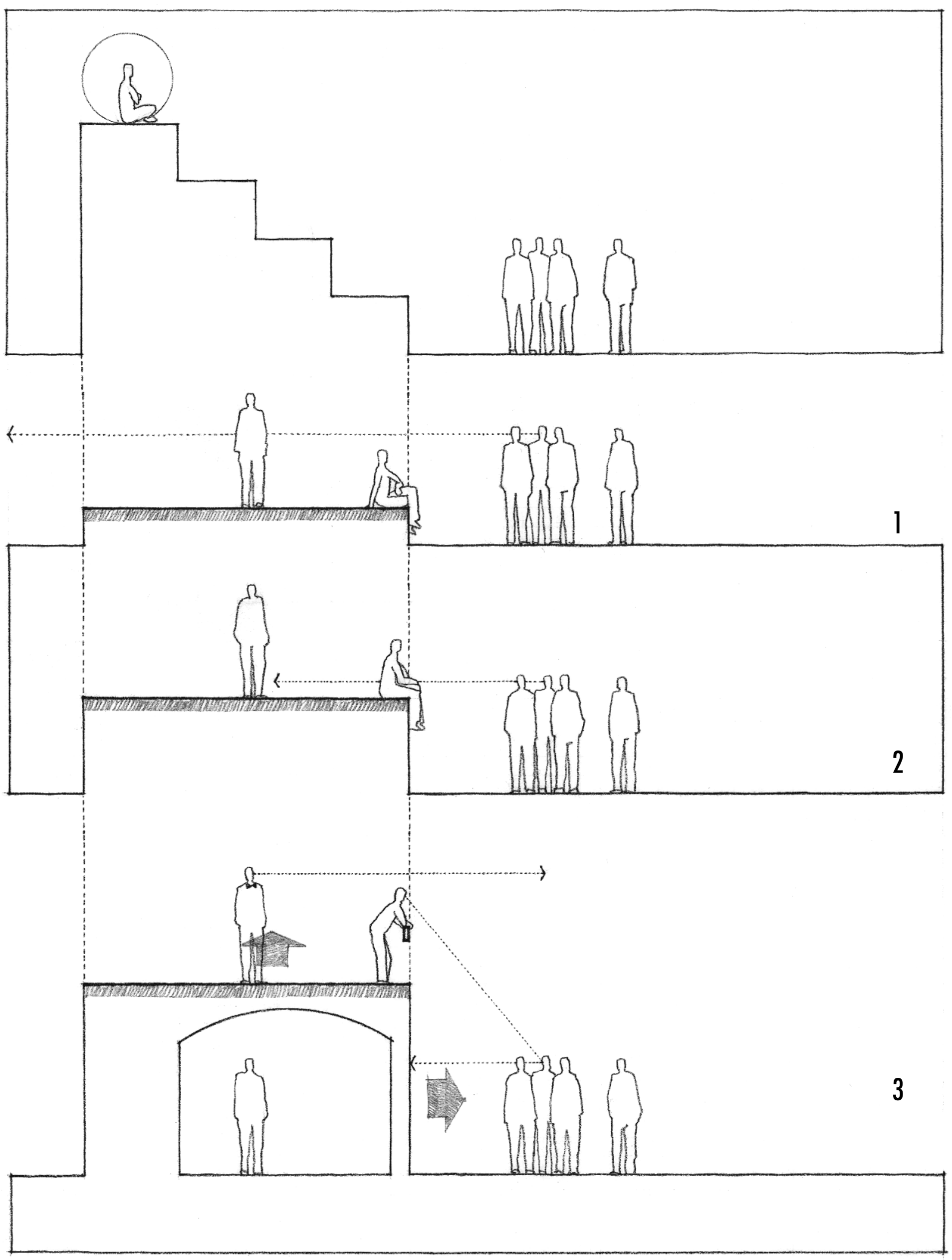
If the surface characteristics of the base plane continue up and across the elevated plane, then the field of the elevated plane will appear to be very much a part of the surrounding space. If, however, the edge condition is articulated by a change in form, color, or texture, then the field will become a plateau that is separate and distinct from its surroundings.



A special place is established by a platform in an artificial lake surrounded by the emperor's living and sleeping quarters.

Fatehpur Sikri, palace complex of Akbar the Great, Mogul emperor of India, 1569–1574.

The degree to which spatial and visual continuity is maintained between an elevated space and its surroundings depends on the scale of the level change.



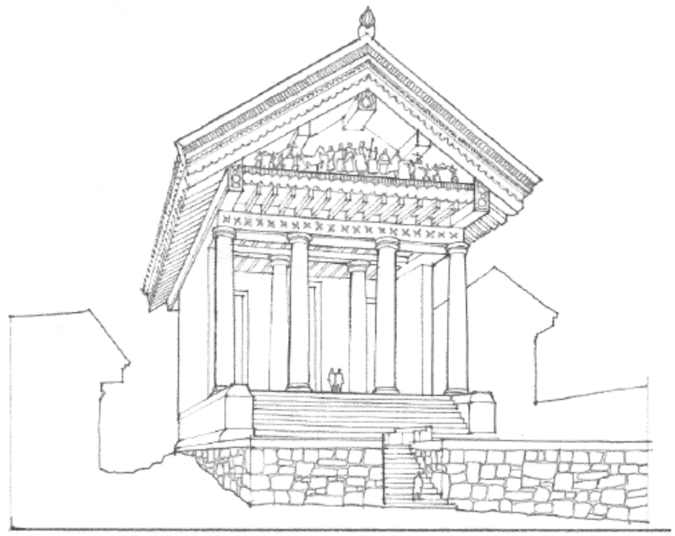
1. The edge of the field is well defined; visual and spatial continuity is maintained; physical access is easily accommodated.

2. Visual continuity is maintained; spatial continuity is interrupted; physical access requires the use of stairs or ramps.

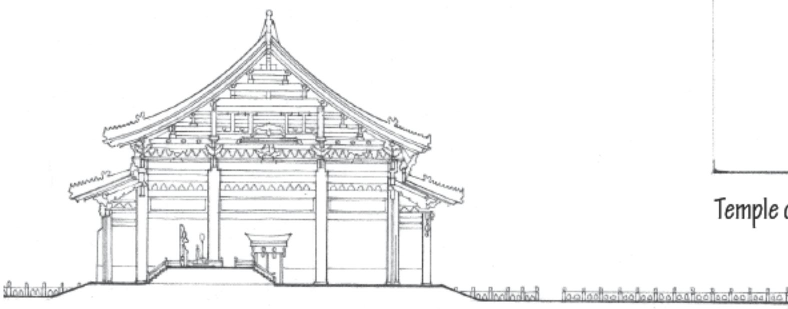
3. Visual and spatial continuity is interrupted; the field of the elevated plane is isolated from the ground or floor plane; the elevated plane is transformed into a sheltering element for the space below.

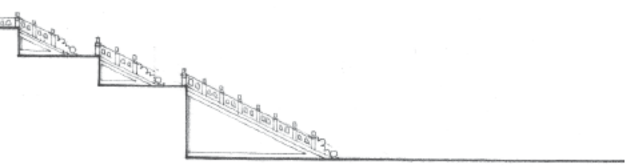
Elevating a portion of the ground plane establishes a platform or podium that structurally and visually supports the form and mass of a building. The elevated ground plane can be a preexisting site condition, or it can be artificially constructed to deliberately raise a building above the surrounding context or enhance its image in the landscape. The examples on this page illustrate how these techniques have been used to venerate sacred and honorific buildings.

Temple Mountain at Bakong Temple, Cambodia, 881 CE

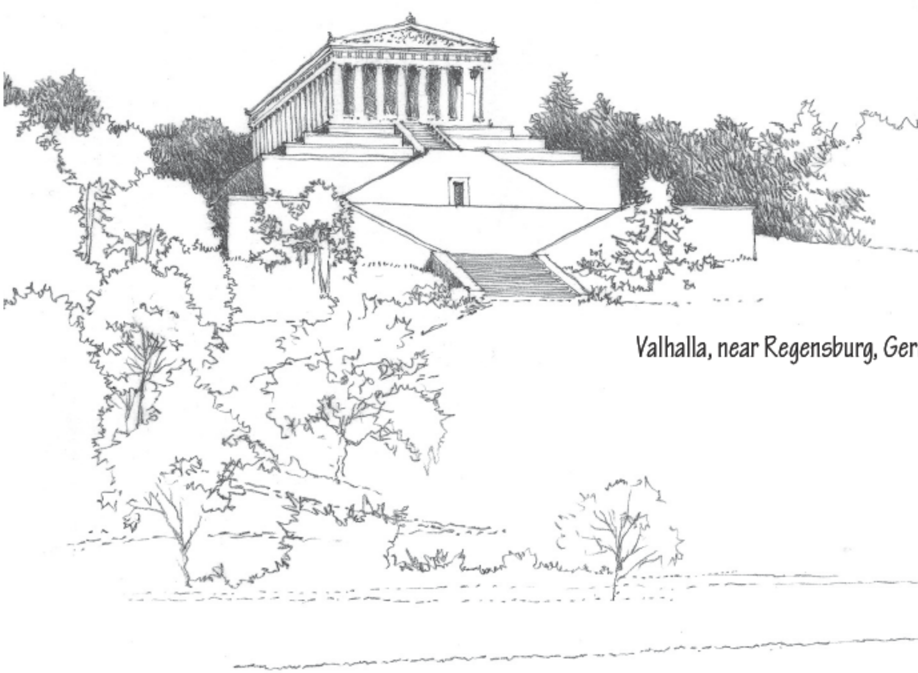


Temple of Jupiter Capitolinus, Rome, 509 BCE





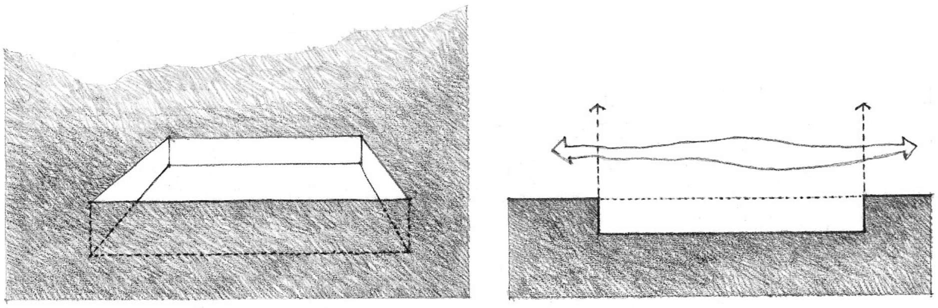
Pavilion of Supreme Harmony in the Forbidden City, Beijing, 1627

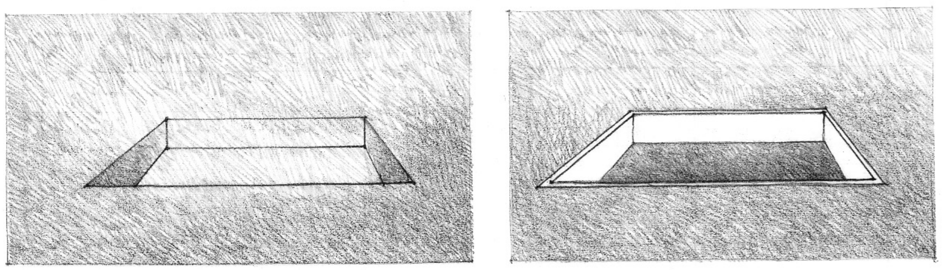


Valhalla, near Regensburg, Germany, Leon von Klenze, 1830–1842

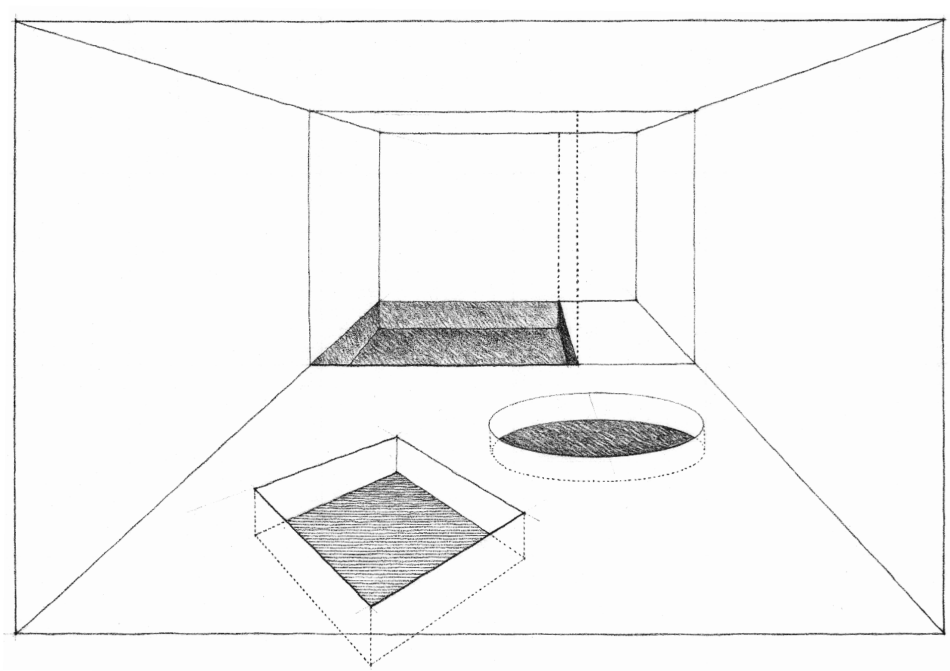
Depressed Base Plane

Lowering a portion of the base plane isolates a field of space from a larger context. The vertical surfaces of the depression establish the boundaries of the field. These boundaries are not implied as in the case of an elevated plane, but are visible edges that begin to form the walls of the space.

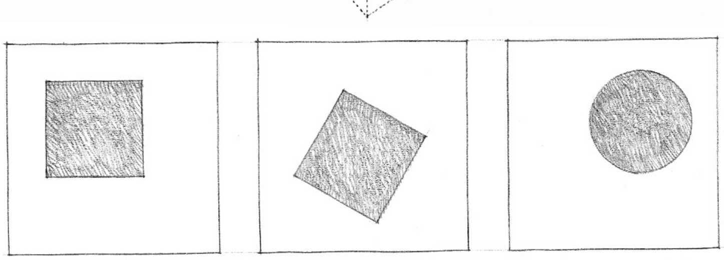


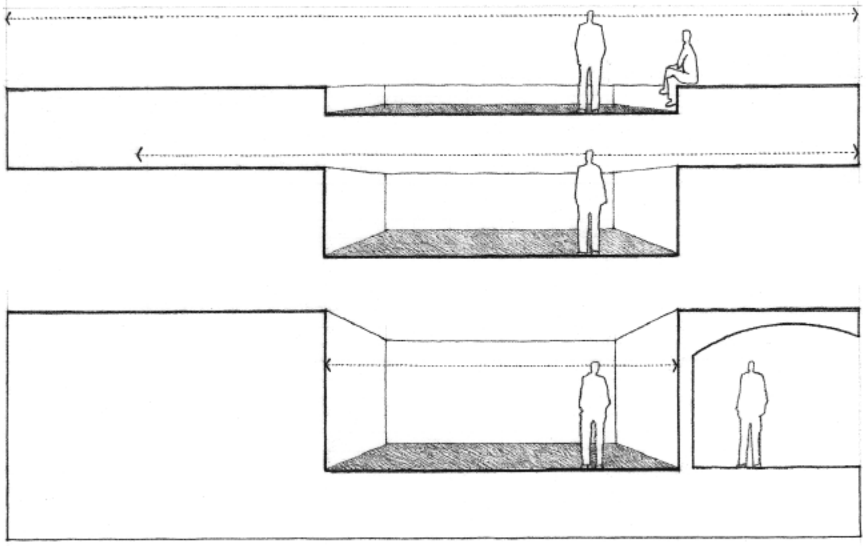


The field of space can be further articulated by contrasting the surface treatment of the lowered area and that of the surrounding base plane.



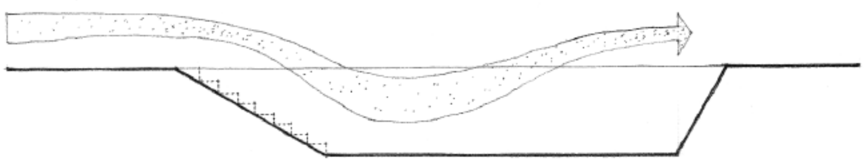
A contrast in form, geometry, or orientation can also visually reinforce the identity and independence of the sunken field from its larger spatial context.



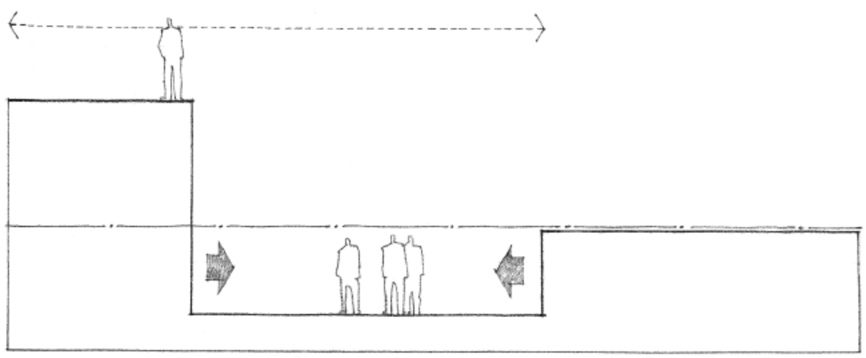


The degree of spatial continuity between a depressed field and the raised area surrounding it depends on the scale of the level change:

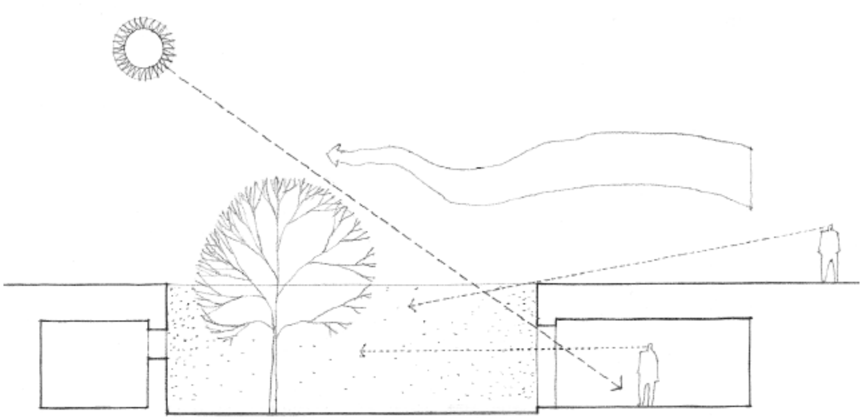
- The depressed field can be an interruption of the ground or floor plane and remain an integral part of the surrounding space.
- Increasing the depth of the depressed field weakens its visual relationship with the surrounding space and strengthens its definition as a distinct volume of space.
- Once the original base plane is above eye level, the depressed field becomes a separate and distinct room in itself.



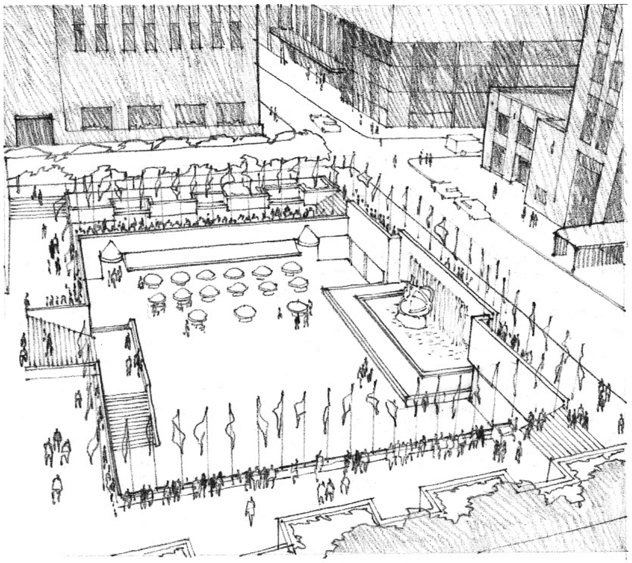
Creating a stepped, terraced, or ramped transition from one level to the next helps promote continuity between a sunken space and the area that rises around it.



Whereas the act of stepping up to an elevated space might express the extroverted nature or significance of the space, the lowering of a space below its surroundings might allude to its introverted nature or to its sheltering and protective qualities.

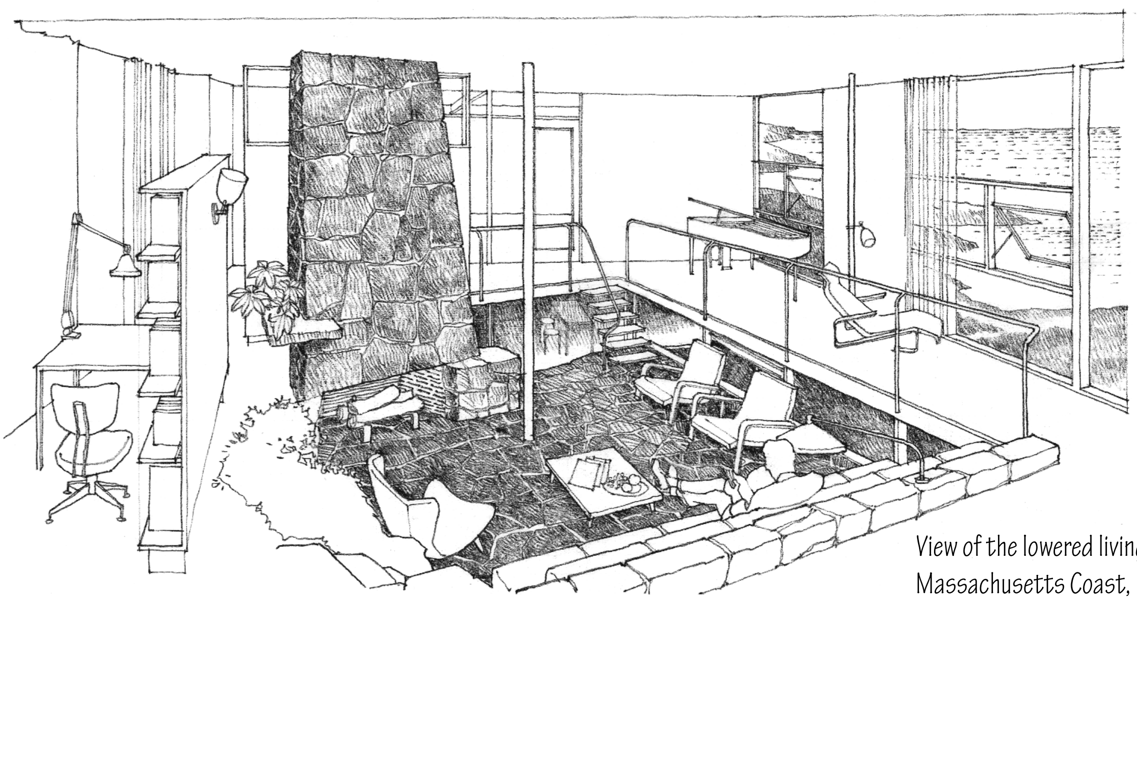


The ground plane can be lowered to define sheltered outdoor spaces for underground buildings. A sunken courtyard, while protected from surface-level wind and noise by the mass surrounding it, remains a source of air, light, and views for the underground spaces opening onto it.



Lower Plaza, Rockefeller Center, New York City, 1930,
Wallace K. Harrison & Max Abramovitz.
Rockefeller Center's lower plaza, an outdoor cafe in the summertime and a skating rink in the winter, can be viewed from the upper plaza while shops open onto it at the lower level.

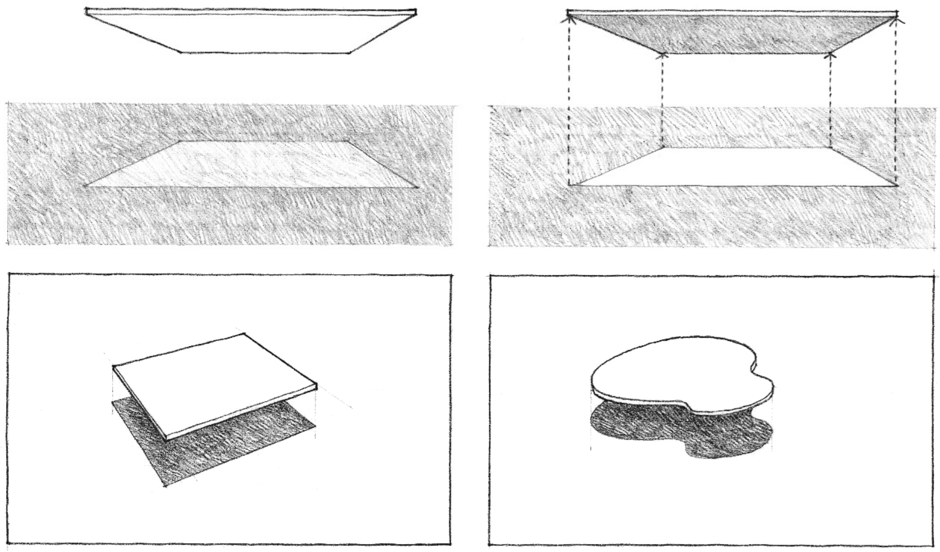
View of library, Wolfsburg Cultural Center, Essen, Germany, 1962, Alvar Aalto



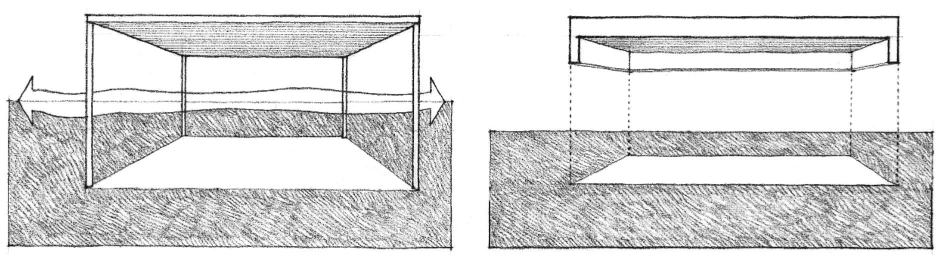
View of the lowered living level, house on the Massachusetts Coast, 1948, Hugh Stubbins

Overhead Plane

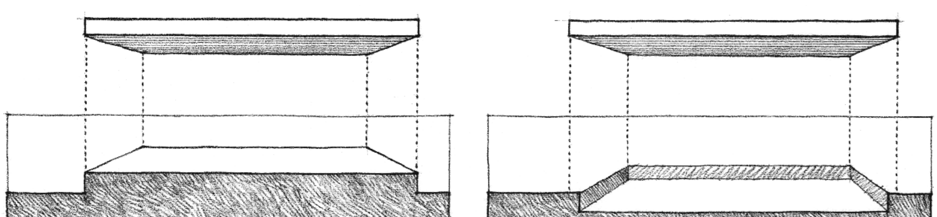
Similar to the manner in which a shade tree offers a sense of enclosure beneath its umbrella structure, an overhead plane defines a field of space between itself and the ground plane. Since the edges of the overhead plane establish the boundaries of this field, its shape, size, and height above the ground plane determines the formal qualities of the space.



While the previous manipulations of the ground or floor plane defined fields of space whose upper limits were established by their context, an overhead plane has the ability to define a discrete volume of space virtually by itself.



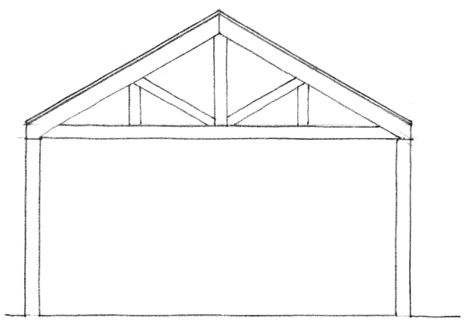
If vertical linear elements such as columns or posts are used to support the overhead plane, they will aid in visually establishing the limits of the defined space without disrupting the flow of space through the field.



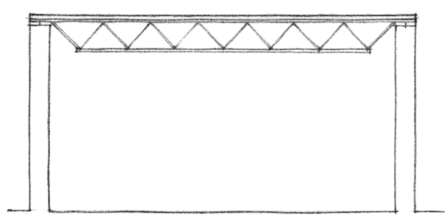
Similarly, if the edges of the overhead plane are turned downward, or if the base plane beneath it is articulated by a change in level, the boundaries of the defined volume of space will be visually reinforced.

Moving the roof of a house in Guinea

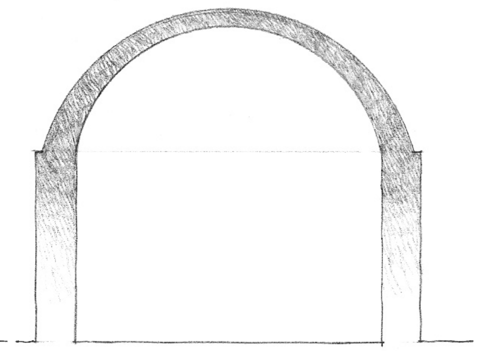
The major overhead element of a building is its roof plane. It not only shelters the interior spaces of a building from sun, rain, and snow, but also has a major impact on the overall form of a building and the shaping of its spaces. The form of the roof plane, in turn, is determined by the material, geometry, and proportions of its structural system and the manner in which it transfers its loads across space to its supports.



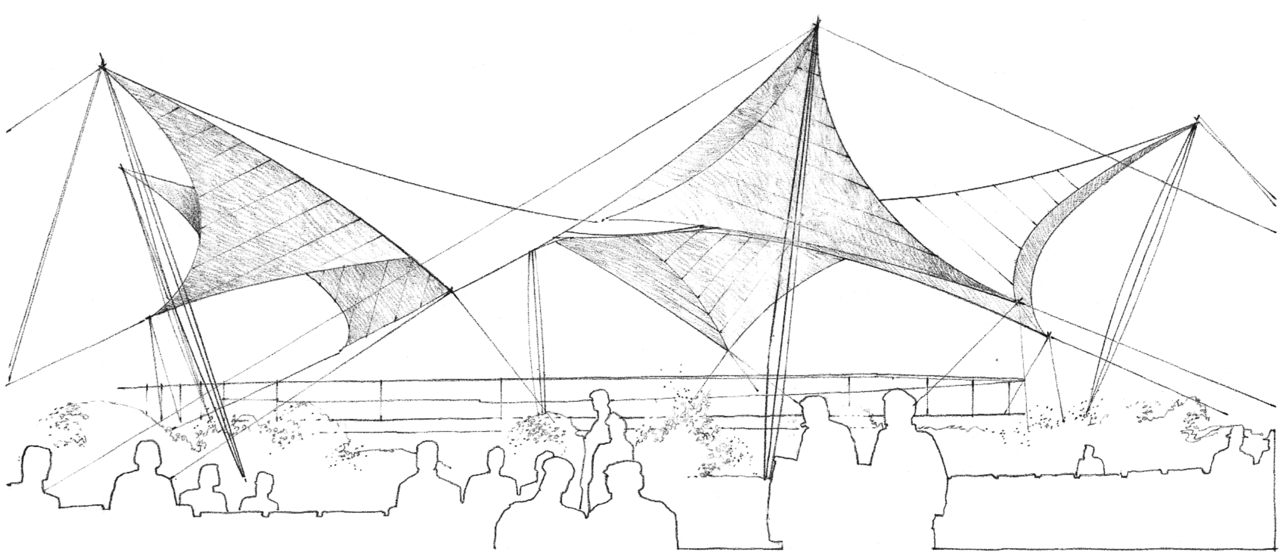
Wood truss



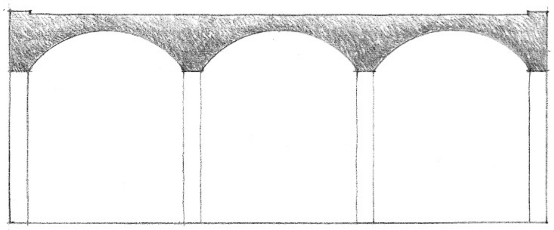
Steel joist

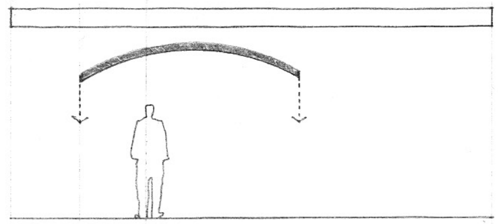


Masonry vault

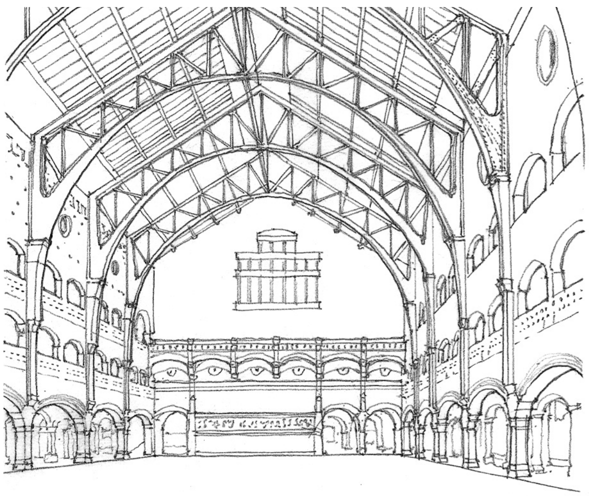


Tensile structure, National Garden Show, Cologne, Germany, 1957, Frei Otto

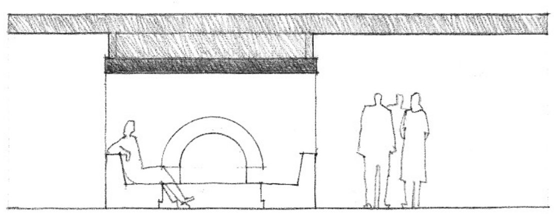


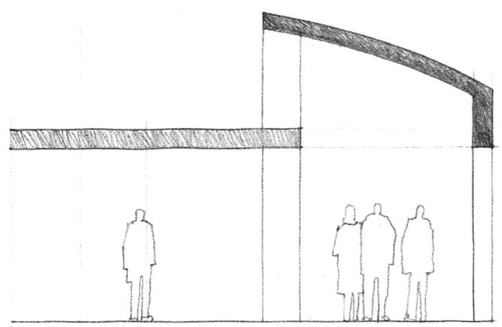


The ceiling plane of an interior space can reflect the form of the structural system supporting the overhead floor or roof plane. Since it need not resist any weathering forces nor carry any major loads, the ceiling plane can also be detached from the floor or roof plane and become a visually active element in a space.

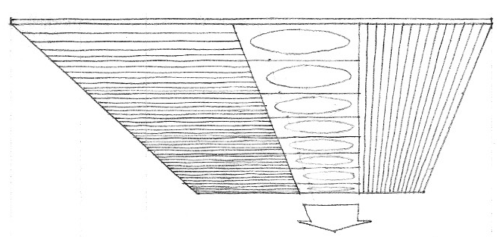


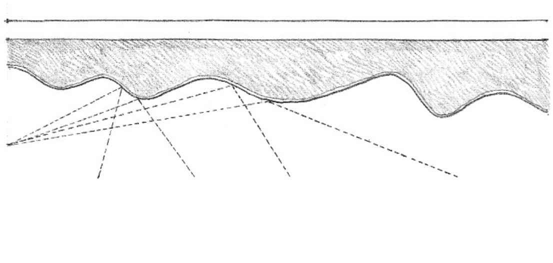
Bandung Institute of Technology, Bandung, Indonesia, 1920, Henri Maclaine Pont





As in the case of the base plane, the ceiling plane can be manipulated to define and articulate zones of space within a room. It can be lowered or elevated to alter the scale of a space, define a path of movement through it, or allow natural light to enter it from above.

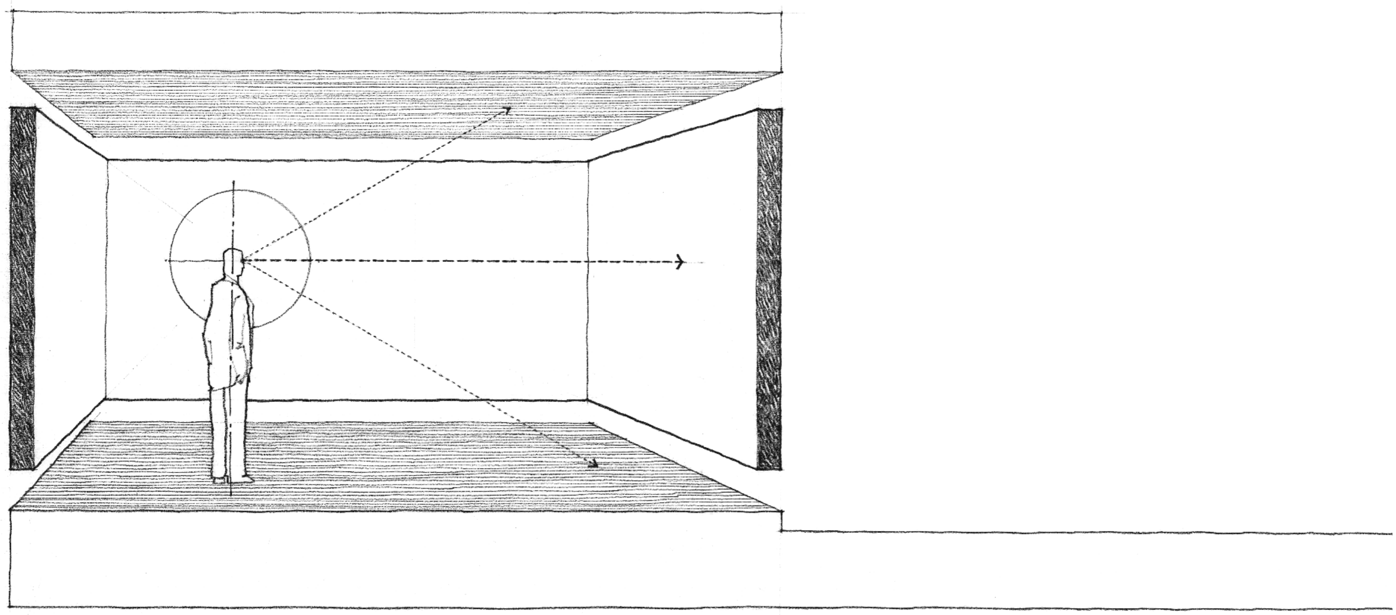


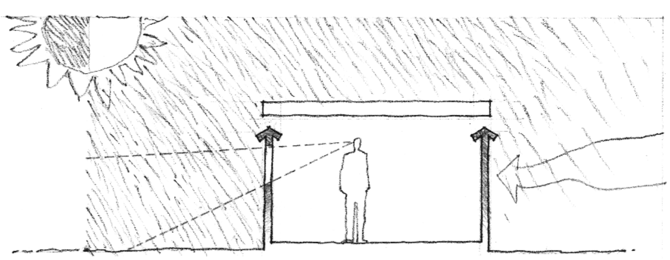


The form, color, texture, and pattern of the ceiling plane can be manipulated as well to improve the quality of light or sound within a space or give it a directional quality or orientation.

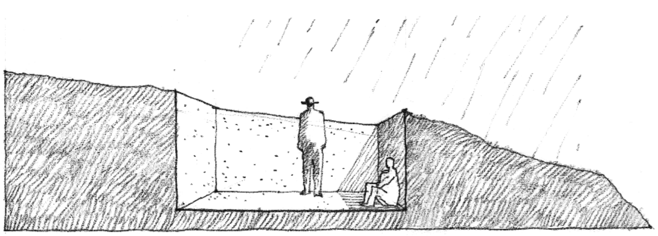
Vertical Elements Defining Space

In the previous section of this chapter, horizontal planes defined fields of space in which the vertical boundaries were implied rather than explicitly described. The following section discusses the critical role vertical elements of form play in firmly establishing the visual limits of a spatial field.

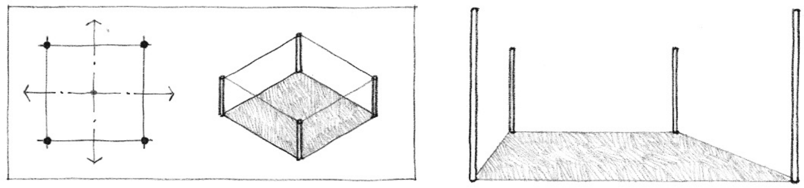




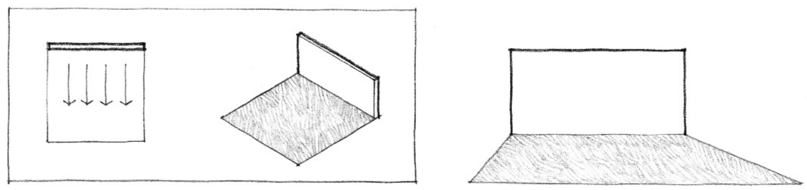
Vertical forms have a greater presence in our visual field than horizontal planes and are, therefore, more instrumental in defining a discrete volume of space and providing a sense of enclosure and privacy for those within it. In addition, they serve to separate one space from another and establish a common boundary between the interior and exterior environments.



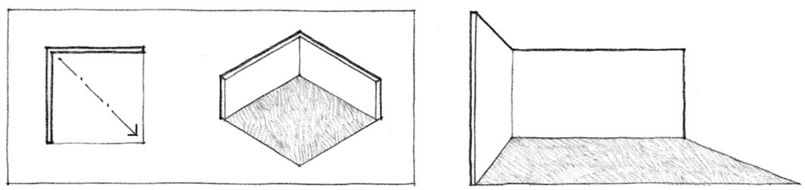
Vertical elements of form also play important roles in the construction of architectural forms and spaces. They serve as structural supports for floor and roof planes. They provide shelter and protection from the climatic elements and aid in controlling the flow of air, heat, and sound into and through the interior spaces of a building.



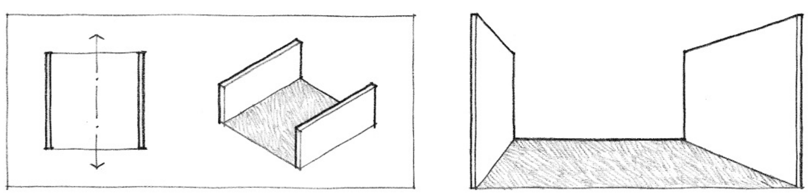
Vertical Linear Elements
Vertical linear elements define the perpendicular edges of a volume of space.



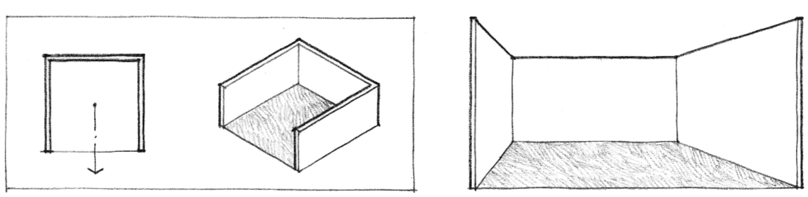
Single Vertical Plane
A single vertical plane articulates the space on which it fronts.



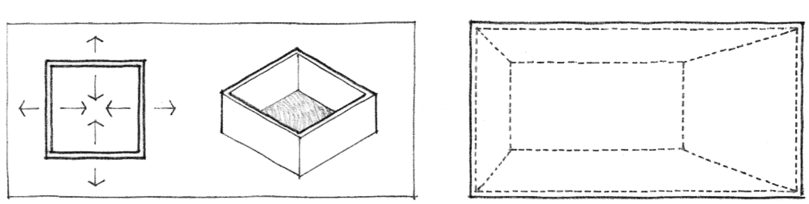
L-Shaped Planes
An L-shaped configuration of vertical planes generates a field of space from its corner outward along a diagonal axis.



Parallel Planes
Two parallel vertical planes define a volume of space between them that is oriented axially toward both open ends of the configuration.



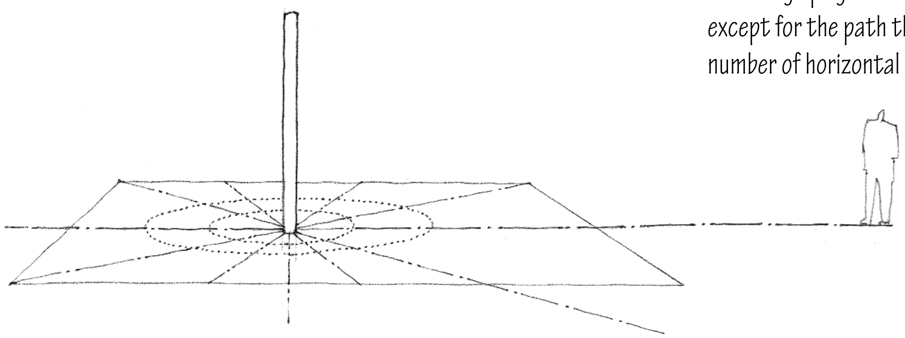
U-Shaped Planes
A U-shaped configuration of vertical planes defines a volume of space that is oriented primarily toward the open end of the configuration.

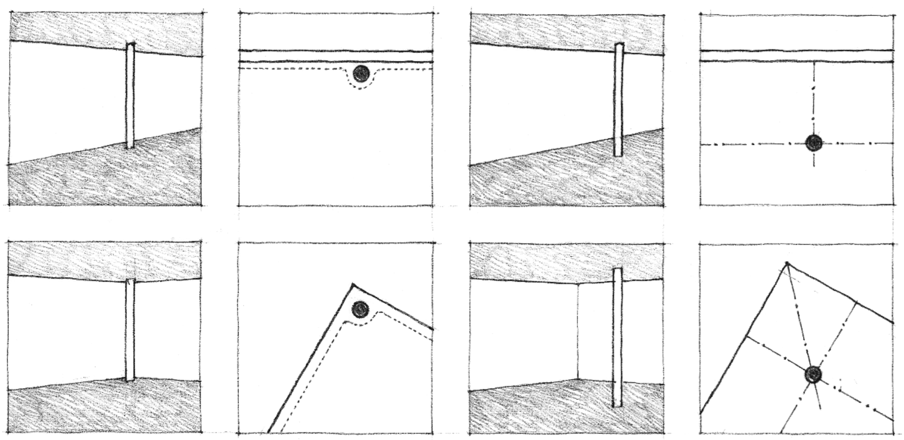


Four Planes: Closure
Four vertical planes establish the boundaries of an introverted space and influence the field of space around the enclosure.

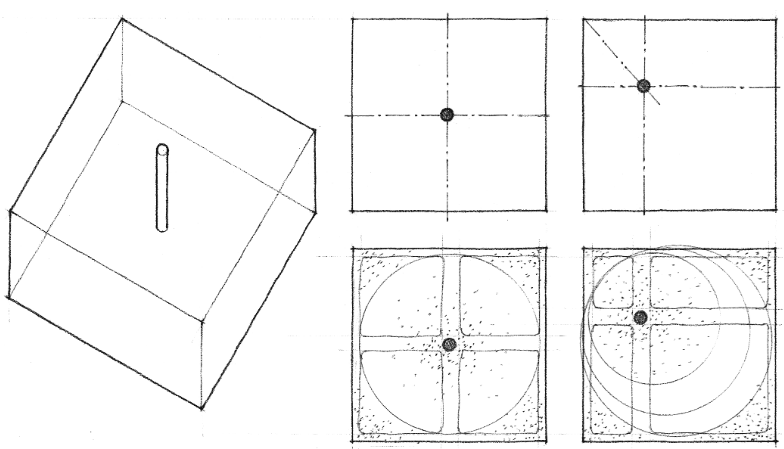
Vertical Linear Elements

A vertical linear element, such as a column, obelisk, or tower, establishes a point on the ground plane and makes it visible in space. Standing upright and alone, a slender linear element is nondirectional except for the path that would lead us to its position in space. Any number of horizontal axes can be made to pass through it.



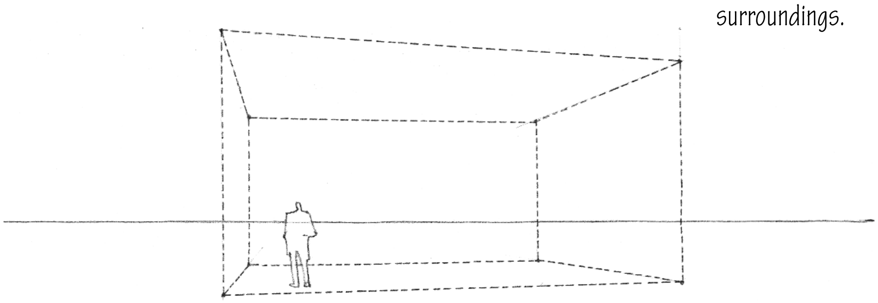


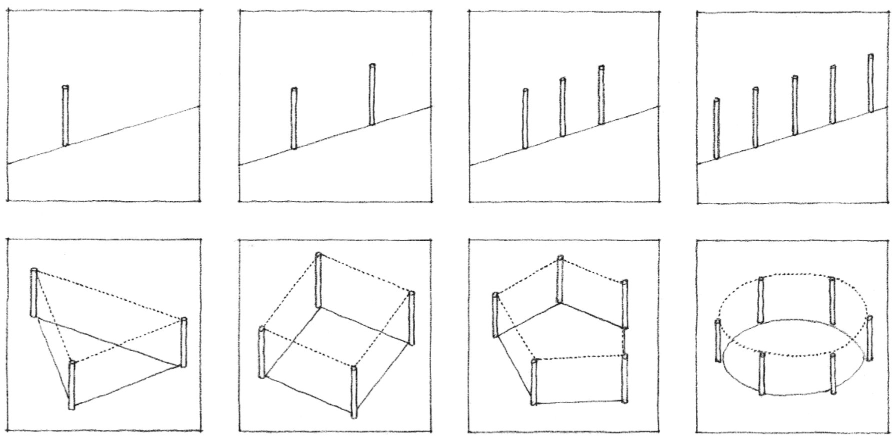
When located within a defined volume of space, a column will generate a spatial field about itself and interact with the spatial enclosure. A column attached to a wall buttresses the plane and articulates its surface. At the corner of a space, a column punctuates the meeting of two wall planes. Standing free within a space, a column defines zones of space within the enclosure.



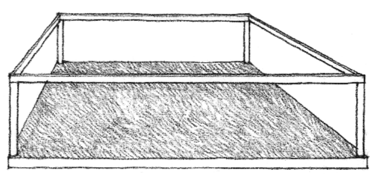
When centered in a space, a column will assert itself as the center of the field and define equivalent zones of space between itself and the surrounding wall planes. When offset, the column will define hierarchical zones of space differentiated by size, form, and location.

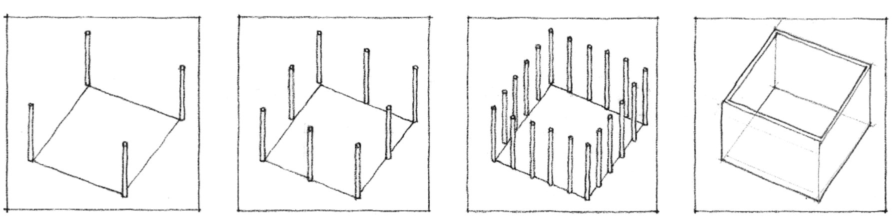
No volume of space can be established without the definition of its edges and corners. Linear elements serve this purpose in marking the limits of spaces that require visual and spatial continuity with their surroundings.



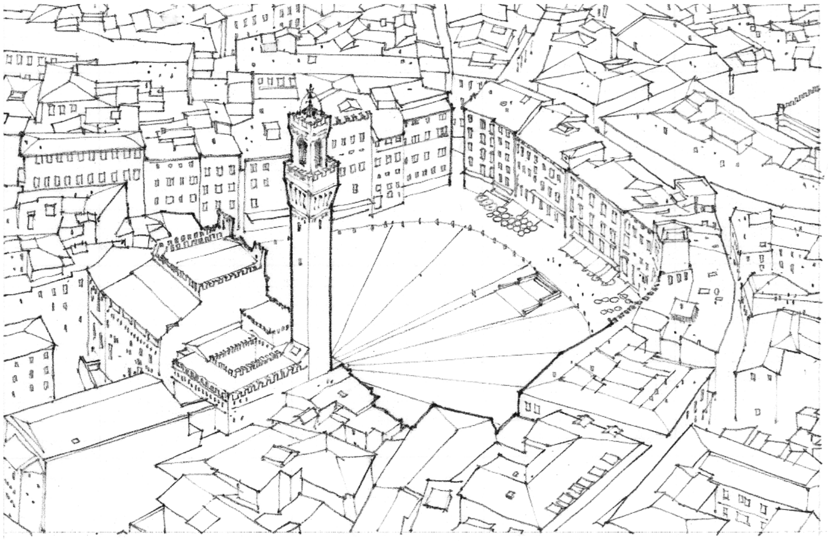


Two columns establish a transparent spatial membrane by the visual tension between their shafts. Three or more columns can be arranged to define the corners of a volume of space. This space does not require a larger spatial context for its definition, but relates freely to it.



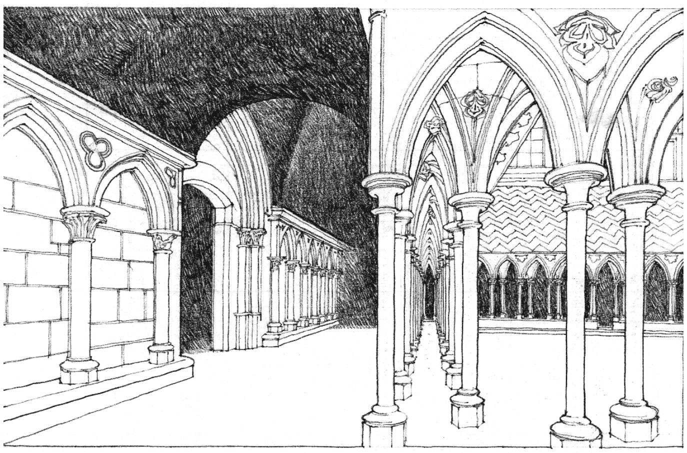


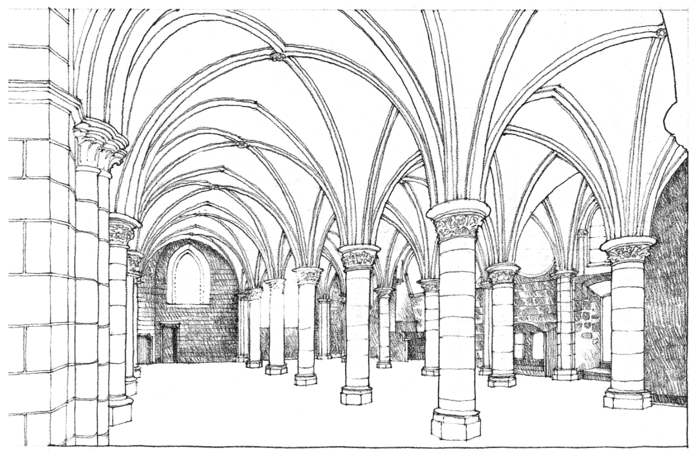
The edges of the volume of space can be visually reinforced by articulating its base plane and establishing its upper limits with beams spanning the columns or with an overhead plane. A repetitive series of column elements along its perimeter would further strengthen the definition of the volume.



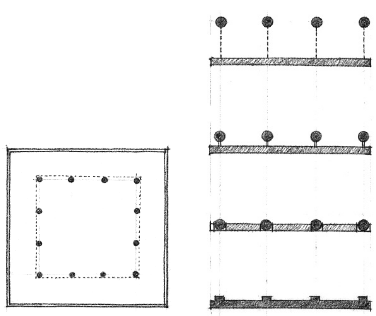
Piazza del Campo, Siena, Italy

Vertical linear elements can terminate an axis, mark the center of an urban space, por provide a focus for an urban space along its edge.

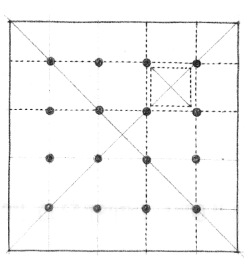




Cloister and Salle des Chevaliers, Mont S. Michel, France, 1203–1228



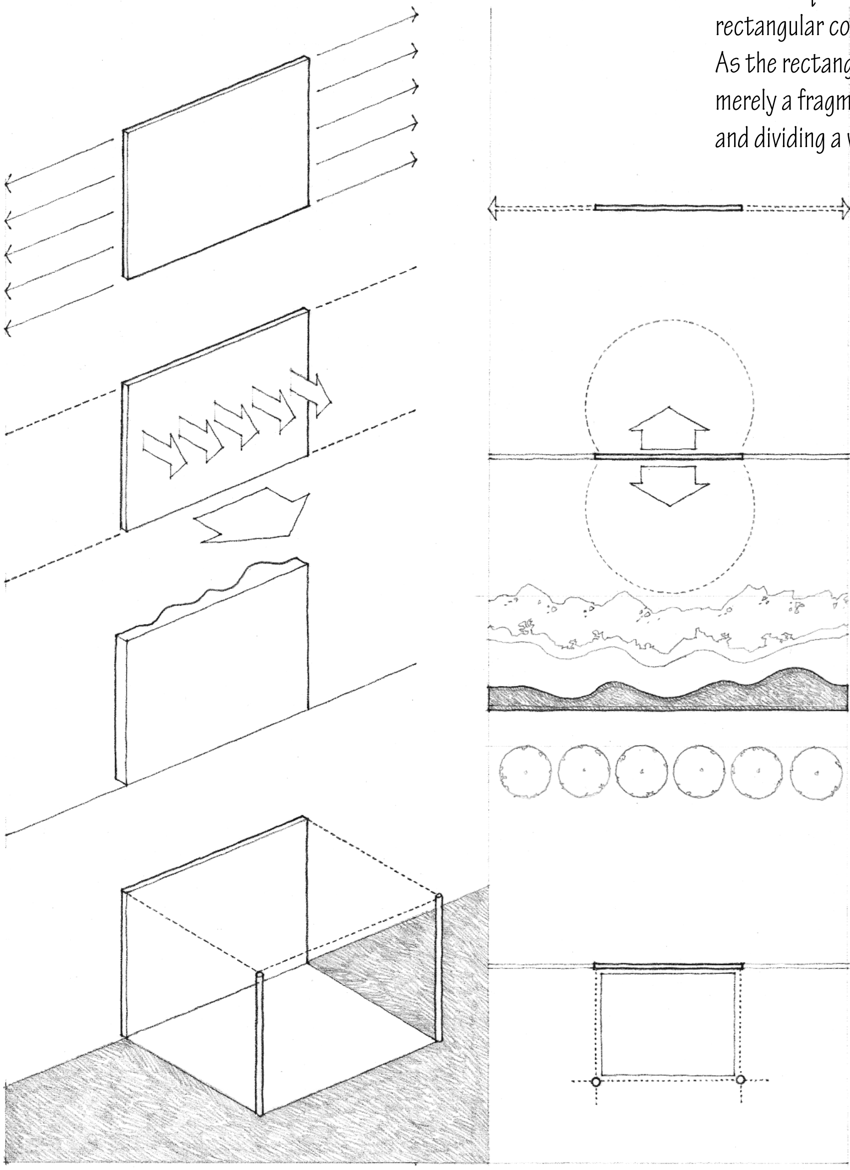
A regularly-spaced series of columns or similar vertical elements form a colonnade. This archetypal element in the vocabulary of architectural design effectively defines an edge of a spatial volume while permitting visual and spatial continuity to exist between the space and its surroundings. A row of columns can also engage a wall and become a pilastrade that supports the wall, articulates its surface, and tempers the scale, rhythm, and proportioning of its bays.



A grid of columns within a large room or hall not only serves to support the floor or roof plane above. The orderly rows of columns also punctuate the spatial volume, mark off modular zones within the spatial field, and establish a measurable rhythm and scale which make the spatial dimensions comprehensible.

Single Vertical Plane

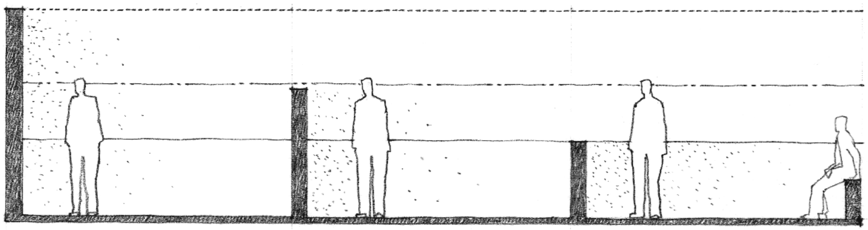
A single vertical plane, standing alone in space, has visual qualities uniquely different from those of a freestanding column. A round column has no preferred direction except for its vertical axis. A square column has two equivalent sets of faces and, therefore, two identical axes. A rectangular column also has two axes, but they differ in their effect. As the rectangular column becomes more like a wall, it can appear to be merely a fragment of an infinitely larger or longer plane, slicing through and dividing a volume of space.



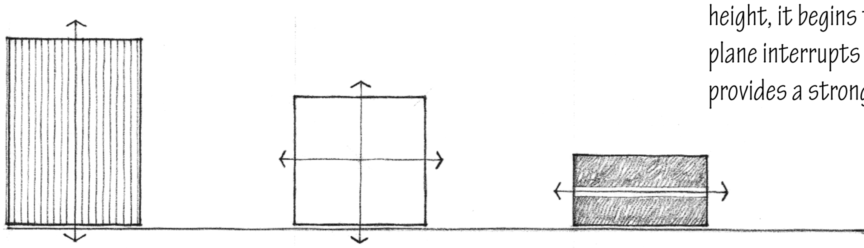
A vertical plane has frontal qualities. Its two surfaces or faces front on and establish the edges of two separate and distinct spatial fields.

These two faces of a plane can be equivalent and front similar spaces, or they can be differentiated in form, color, or texture, in order to respond to or articulate different spatial conditions. A vertical plane can, therefore, have either two fronts or a front and a back.

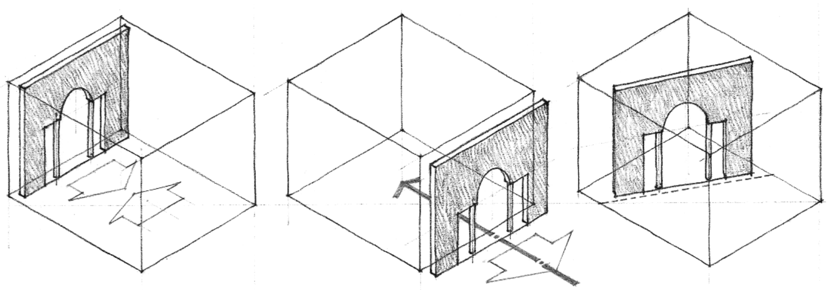
The field of space on which a single vertical plane fronts is not well defined. The plane by itself can establish only a single edge of the field. To define a three-dimensional volume of space, the plane must interact with other elements of form.



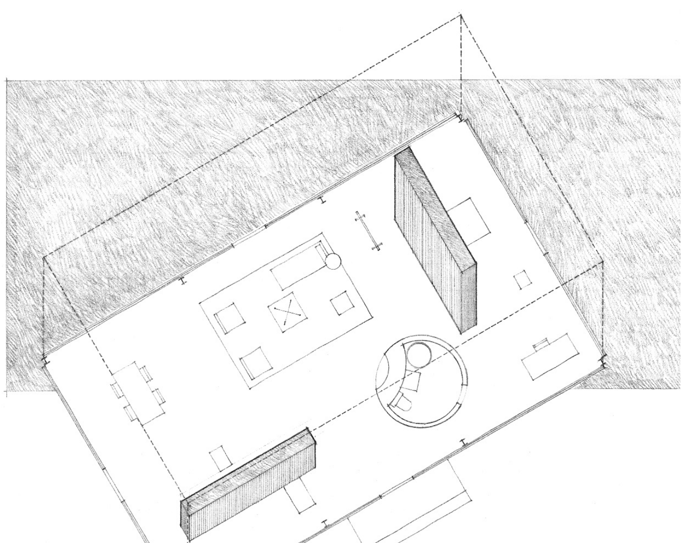
The height of a vertical plane relative to our body height and eye level is the critical factor that affects the ability of the plane to visually describe space. When 2 feet (610) high, a plane defines the edge of a spatial field but provides little or no sense of enclosure. When waist high, it begins to provide a sense of enclosure while allowing for visual continuity with the adjoining space. When it approaches eye level in height, it begins to separate one space from another. Above our height, a plane interrupts the visual and spatial continuity between two fields and provides a strong sense of enclosure.



The surface color, texture, and pattern of a plane affect our perception of its visual weight, scale, and proportions.



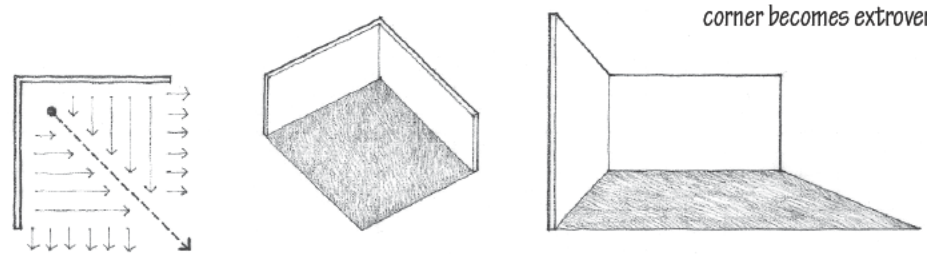
When related to a defined volume of space, a vertical plane can be the primary face of the space and give it a specific orientation. It can front the space and define a plane of entry into it. It can be a freestanding element within a space and divide the volume into two separate but related areas.

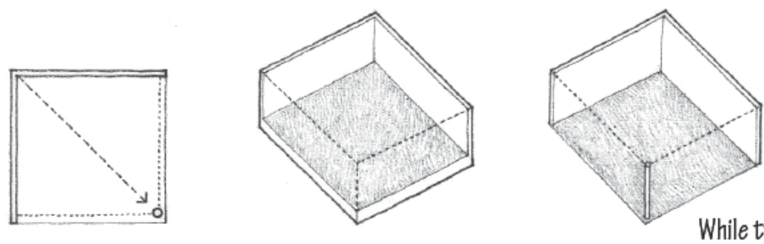


Glass House, New Canaan, Connecticut, 1949, Philip Johnson

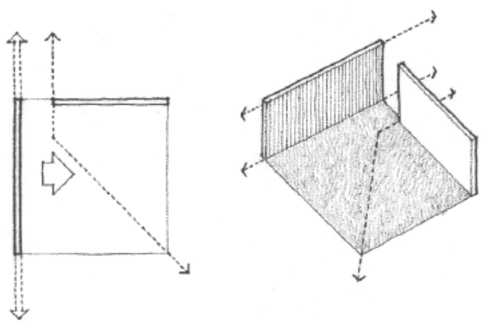
L-Shaped Configuration of Planes

An L-shaped configuration of vertical planes defines a field of space along a diagonal from its corner outward. While this field is strongly defined and enclosed at the corner of the configuration, it dissipates rapidly as it moves away from the corner. The introverted field at the interior corner becomes extroverted along its outer edges.

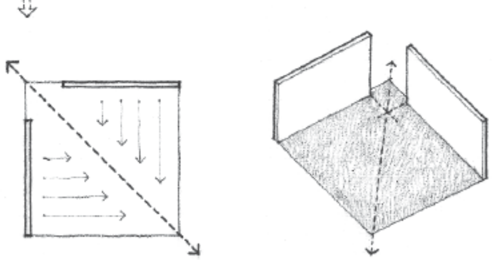




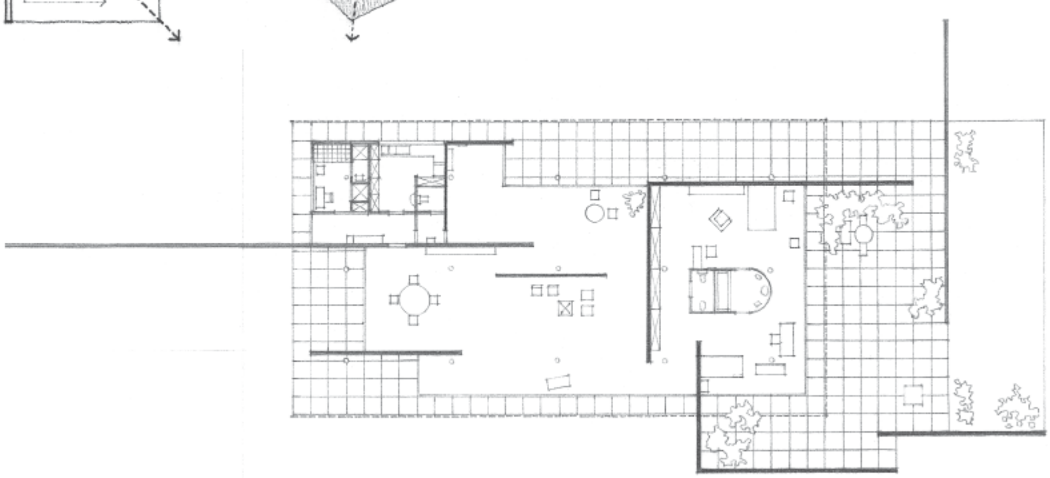
While two edges of the field are clearly defined by the two planes of the configuration, its other edges remain ambiguous unless further articulated by additional vertical elements, manipulations of the base plane, or an overhead plane.



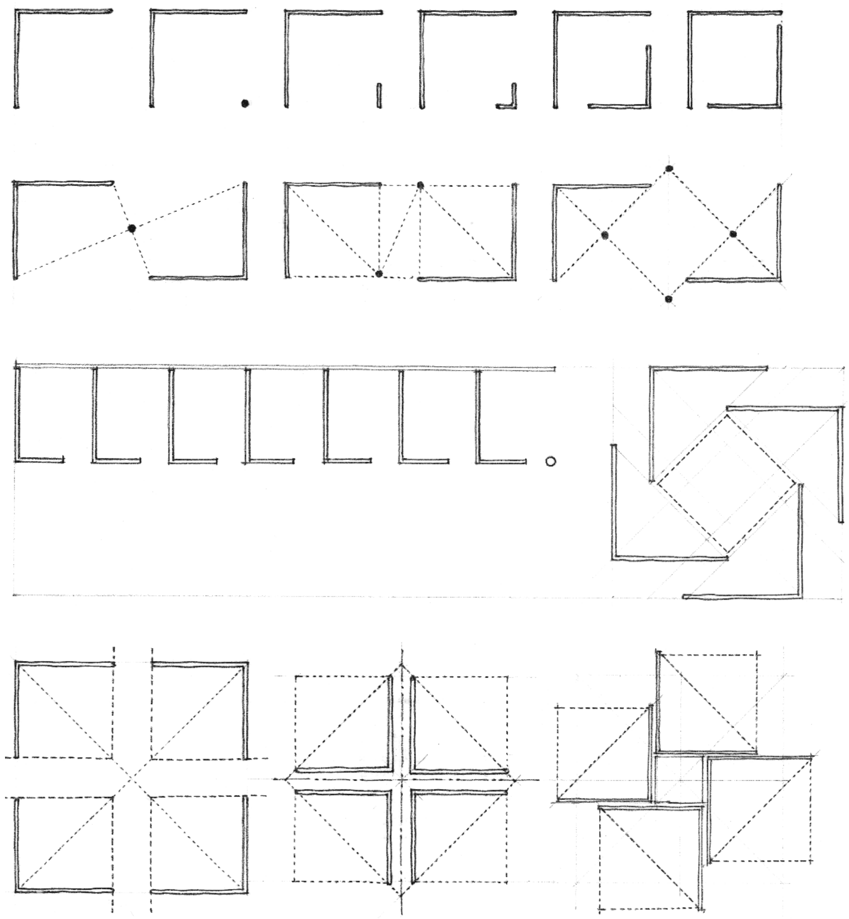
If a void is introduced to one side of the corner of the configuration, the definition of the field will be weakened. The two planes will be isolated from each other, and one will appear to slide by and visually dominate the other.



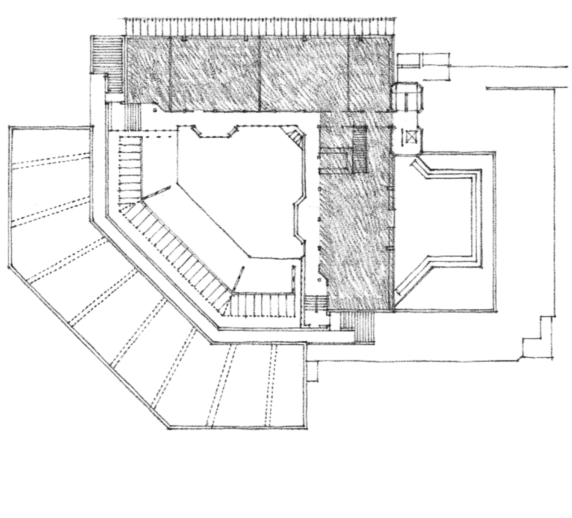
If neither plane extends to the corner, the field will become more dynamic and organize itself along the diagonal of the configuration.

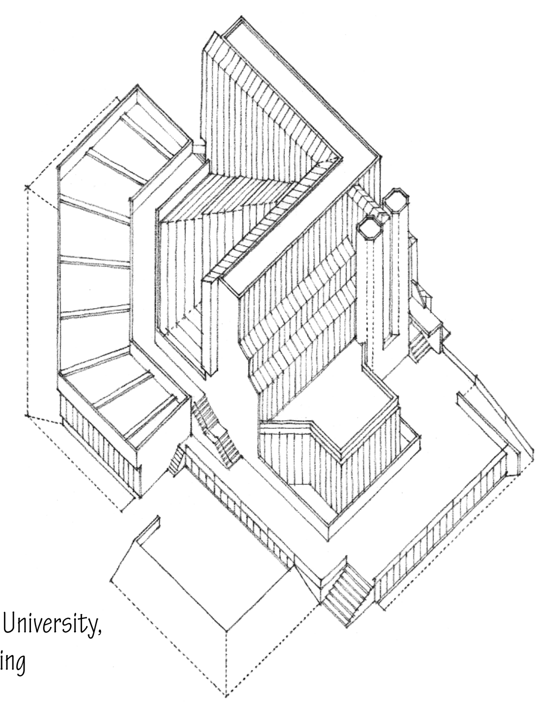


Berlin Building Exposition House, 1931, Mies van der Rohe



L-shaped configurations of planes are stable and self-supporting and can stand alone in space. Because they are open-ended, they are flexible space-defining elements. They can be used in combination with one another or with other elements of form to define a rich variety of spaces.

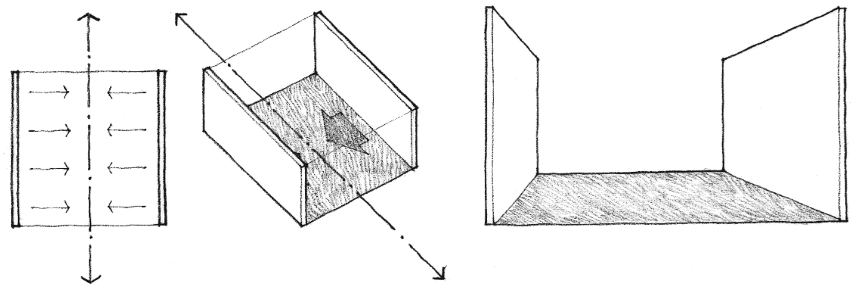


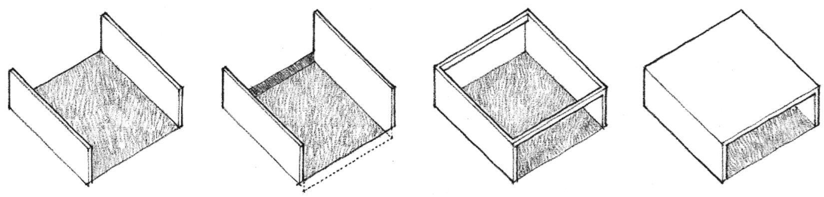


History Faculty Building, Cambridge University, England, 1964–1967, James Stirling

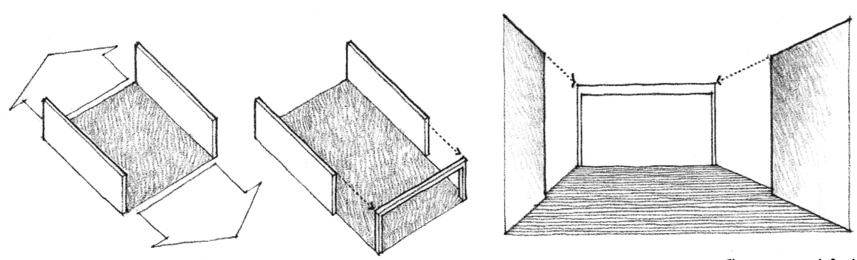
Parallel Vertical Planes

A pair of parallel vertical planes defines a field of space between them. The open ends of the field, established by the vertical edges of the planes, give the space a strong directional quality. Its primary orientation is along the axis about which the planes are symmetrical. Since the parallel planes do not meet to form corners and fully enclose the field, the space is extroverted in nature.

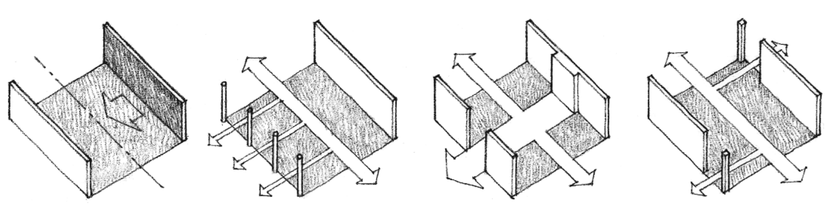




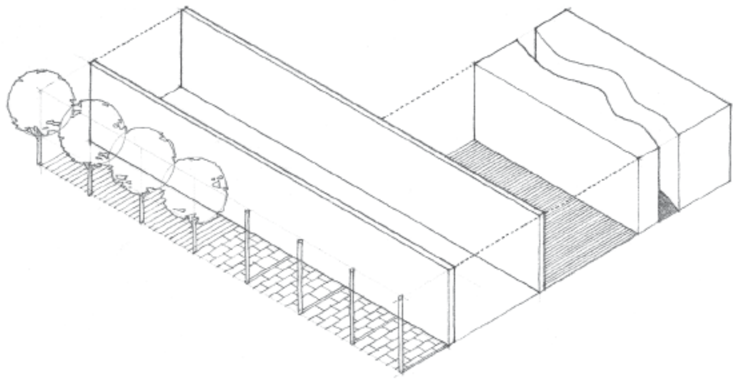
The definition of the spatial field along the open ends of the configuration can be visually reinforced by manipulating the base plane or adding overhead elements to the composition.



The spatial field can be expanded by extending the base plane beyond the open ends of the configuration. This expanded field can, in turn, be terminated by a vertical plane whose width and height is equal to that of the field.

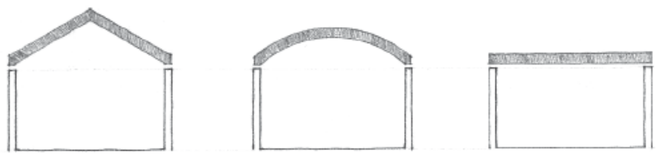


If one of the parallel planes is differentiated from the other by a change in form, color, or texture, a secondary axis, perpendicular to the flow of the space, will be established within the field. Openings in one or both of the planes can also introduce secondary axes to the field and modulate the directional quality of the space.

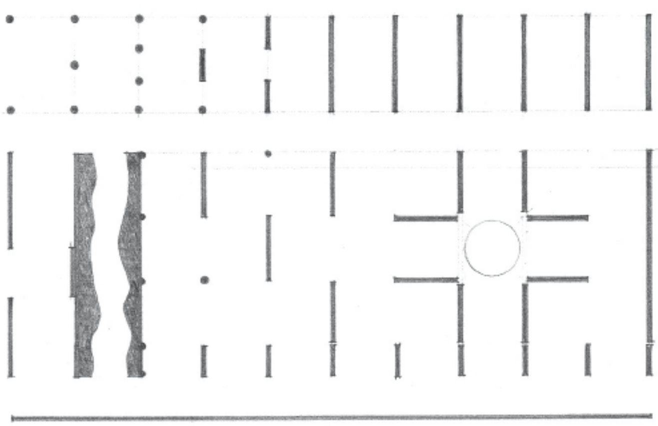


Various elements in architecture can be seen as parallel planes that define a field of space:

- A pair of parallel interior walls within a building
- A street space formed by the facades of two facing buildings
- A colonnaded arbor or pergola
- A promenade or allée bordered by rows of trees or hedges
- A natural topographical form in the landscape

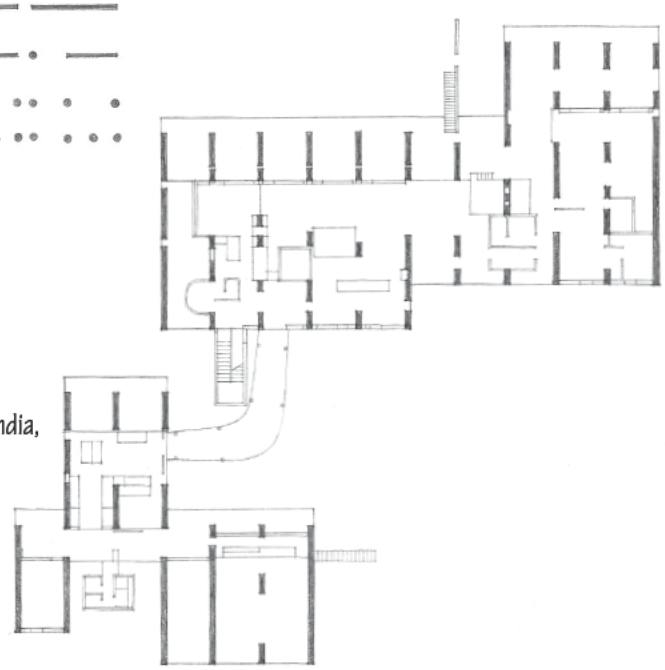


Sets of parallel vertical planes can be transformed into a wide variety of configurations. Their spatial fields can be related to one another either through the open ends of their configurations or through openings in the planes themselves.



The parallel vertical planes of a bearing-wall structural system can be the generating force behind the form and organization of a building. Their repetitive pattern can be modified by varying their length or by introducing voids within the planes to accommodate the dimensional requirements of larger spaces. These voids can also define circulation paths and establish visual relationships perpendicular to the wall planes.

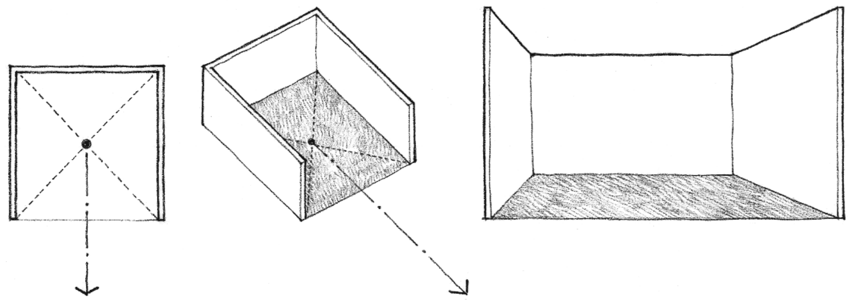
The slots of space defined by parallel wall planes can also be modulated by altering the spacing and configuration of the planes.

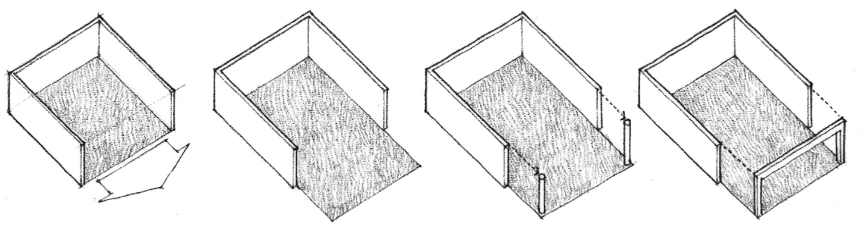


Sarabhai House, Ahmedabad, India, 1955, Le Corbusier

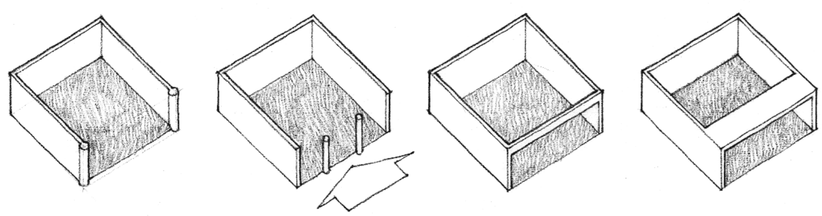
U-Shaped Planes

A U-shaped configuration of vertical planes defines a field of space that has an inward focus as well as an outward orientation. At the closed end of the configuration, the field is well defined. Toward the open end of the configuration, the field becomes extroverted in nature.

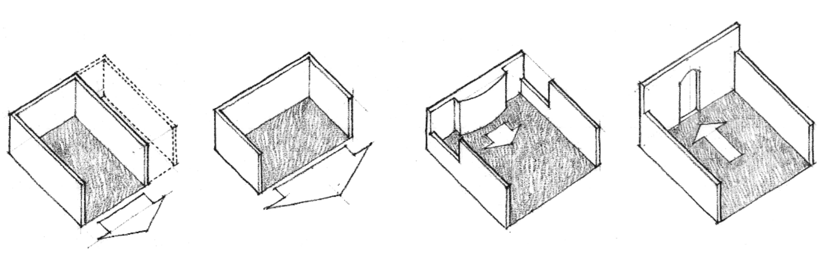




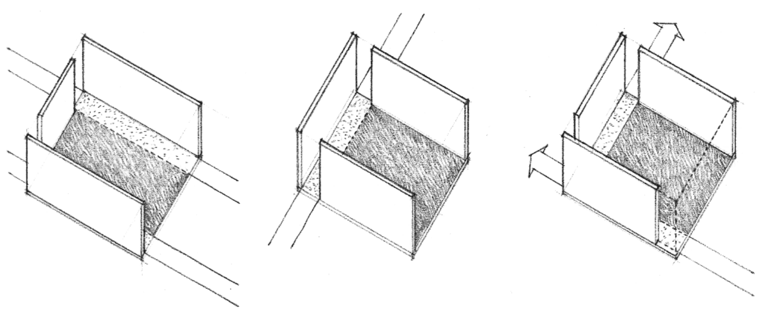
The open end is the primary aspect of the configuration by virtue of its uniqueness relative to the other three planes. It allows the field to have visual and spatial continuity with the adjoining space. The extension of the spatial field into the adjoining space can be visually reinforced by continuing the base plane beyond the open end of the configuration.



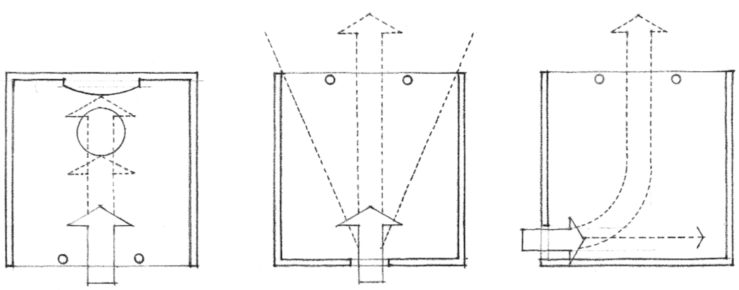
If the plane of the opening is further defined with columns or overhead elements, the definition of the original field will be reinforced and continuity with the adjoining space will be interrupted.



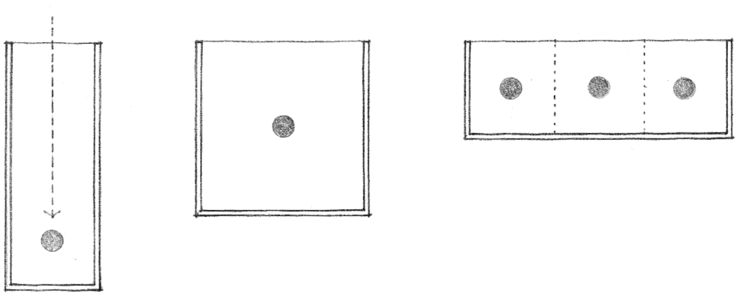
If the configuration of planes is rectangular and oblong in form, the open end can be along its narrow or wide side. In either case, the open end will remain the primary face of the spatial field, and the plane opposite the open end will be the principal element among the three planes of the configuration.



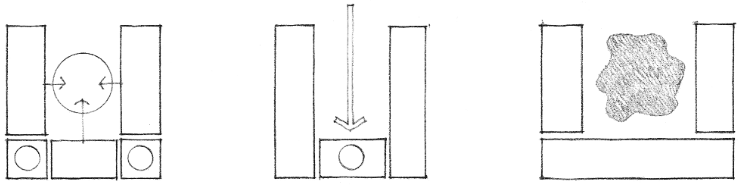
If openings are introduced at the corners of the configuration, secondary zones will be created within a multidirectional and dynamic field.



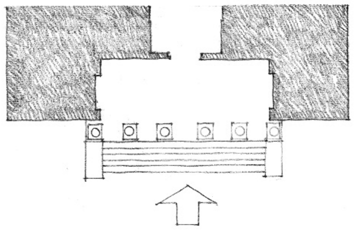
If the field is entered through the open end of the configuration, the rear plane, or a form placed in front of it, will terminate our view of the space. If the field is entered through an opening in one of the planes, the view of what lies beyond the open end will draw our attention and terminate the sequence.



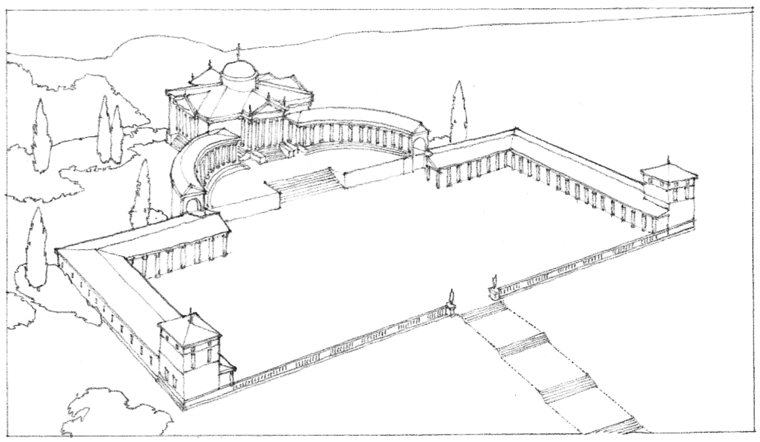
If the end of a long, narrow field is open, the space will encourage movement and induce a progression or sequence of events. If the field is square, or nearly square, the space will be static and have the character of a place to be in, rather than a space to move through. If the side of a long, narrow field is open, the space will be susceptible to a subdivision into a number of zones.



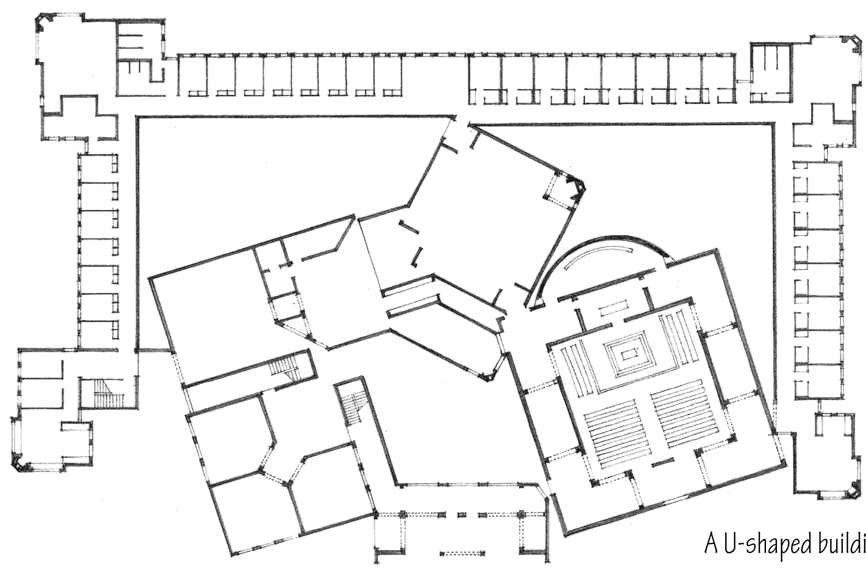
U-shaped configurations of building forms and organizations have the inherent ability to capture and define outdoor space. Their composition can be seen to consist essentially of linear forms. The corners of the configuration can be articulated as independent elements or can be incorporated into the body of the linear forms.



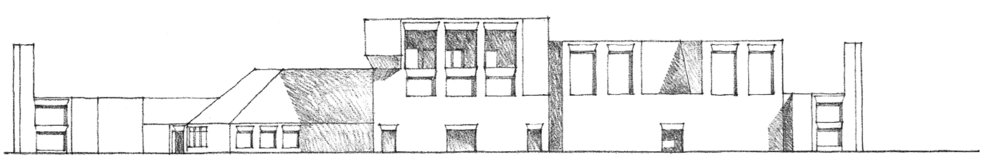
A U-shaped organization can define a forecourt for the approach to a building as well as form an entrance that is recessed within the building volume.



Villa Tressino at Meledo, from Andrea Palladio's
The Four Books of Architecture

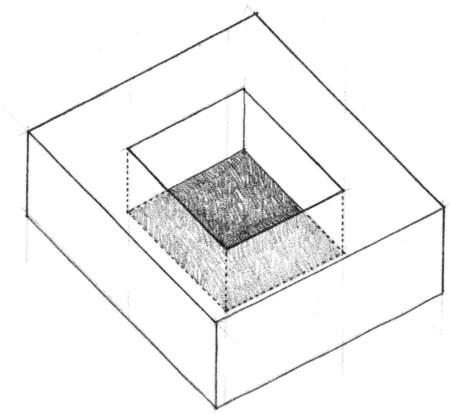


A U-shaped building form can also serve as a container and can organize within its field a cluster of forms and spaces.

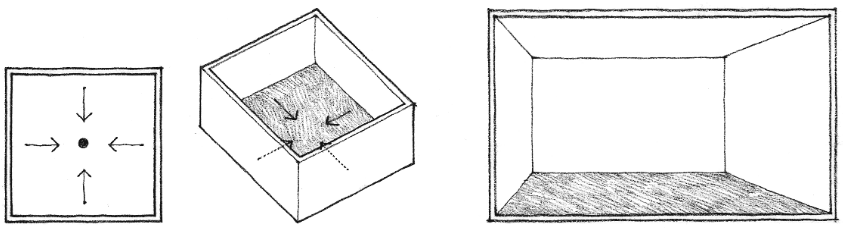


Convent for the Dominican Sisters, 1965–1968, project by Louis Kahn

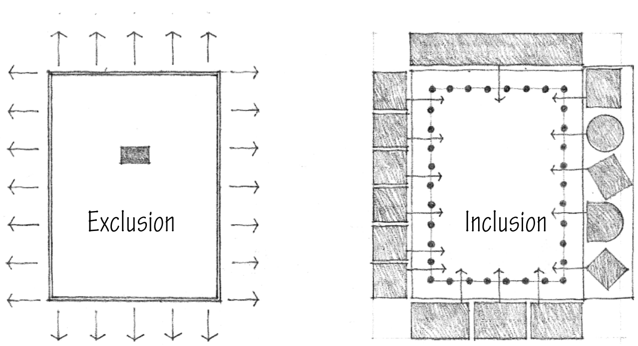
Four Planes: Closure



Four vertical planes encompassing a field of space is probably the most typical, and certainly the strongest, type of spatial definition in architecture. Since the field is completely enclosed, its space is naturally introverted. To achieve visual dominance within a space or become its primary face, one of the enclosing planes can be differentiated from the others by its size, form, surface articulation, or by the nature of the openings within it.

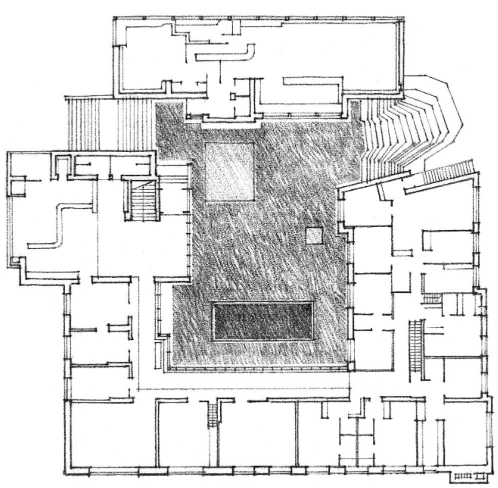


Well-defined, enclosed fields of space can be found in architecture at various scales, from a large urban square, to a courtyard or atrium space, to a single hall or room within a building complex.

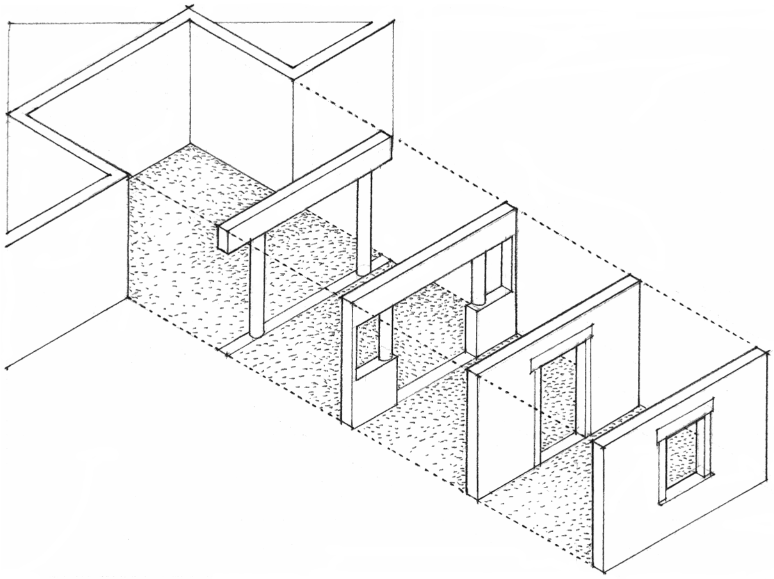


Historically, four planes have often been used to define a visual and spatial field for a sacred or significant building that stands as an object within the enclosure. The enclosing planes may be ramparts, walls, or fences that isolate the field and exclude surrounding elements from the precinct.

In an urban context, a defined field of space can organize a series of buildings along its perimeter. The enclosure may consist of arcades or gallery spaces that promote the inclusion of surrounding buildings into their domain and activate the space they define.



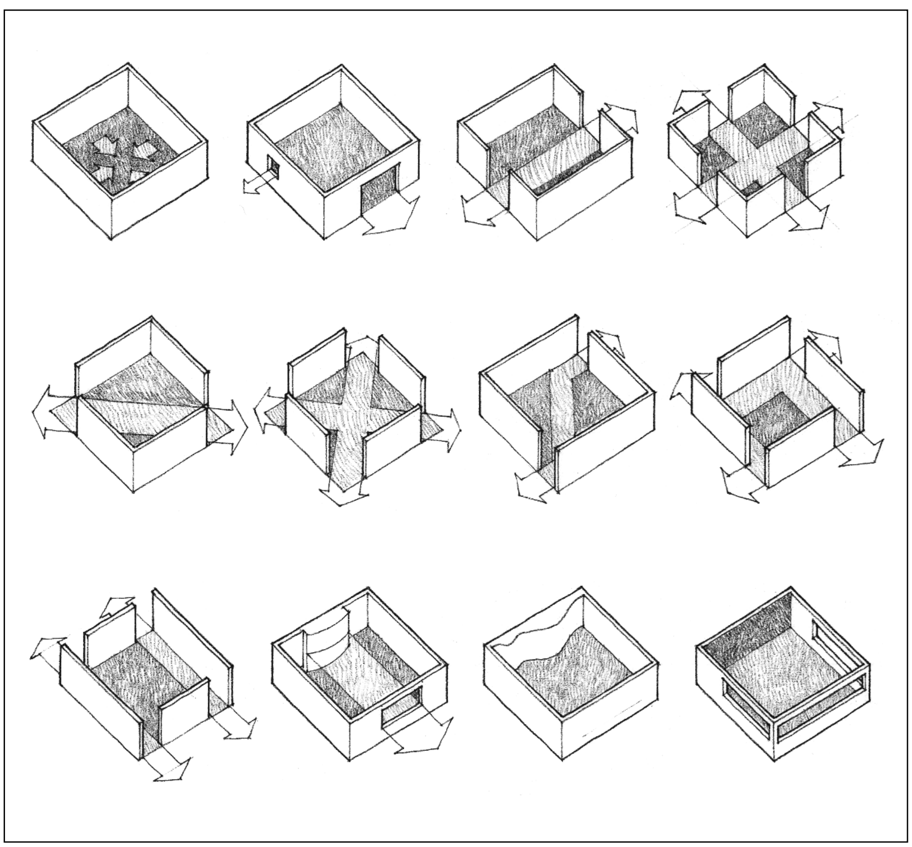
Town Hall, Säynätsalo, Finland, 1950–1952, Alvar Aalto



Openings in Space-Defining Elements

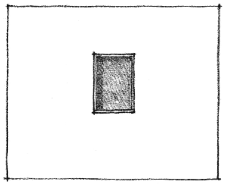
No spatial or visual continuity is possible with adjacent spaces without openings in the enclosing planes of a spatial field. Doors offer entry into a room and influence the patterns of movement and use within it. Windows allow light to penetrate the space and illuminate the surfaces of a room, offer views from the room to the exterior, establish visual relationships between the room and adjacent spaces, and provide for the natural ventilation of the space. While these openings provide continuity with adjacent spaces, they can, depending on their size, number, and location, also begin to weaken the enclosure of the space.

The following section of this chapter focuses on enclosed spaces at the scale of a room, where the nature of the openings within the room's enclosure is a major factor in determining the quality of its space.

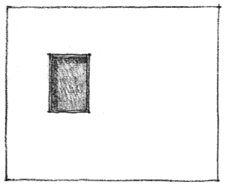


Openings within Planes

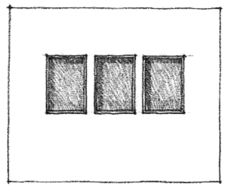
An opening can be located wholly within a wall or ceiling plane and be surrounded on all sides by the surface of the plane.



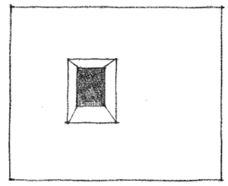
Centered



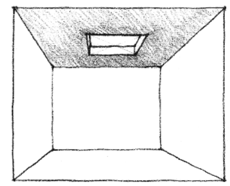
Off-center



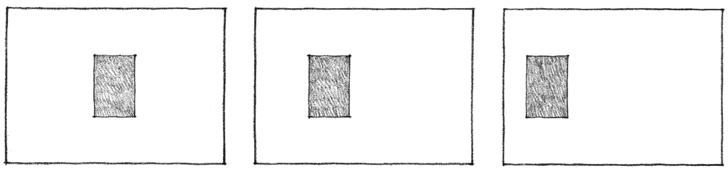
Grouped



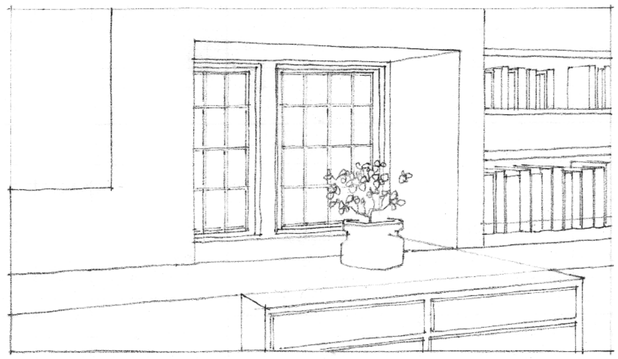
Deep-set

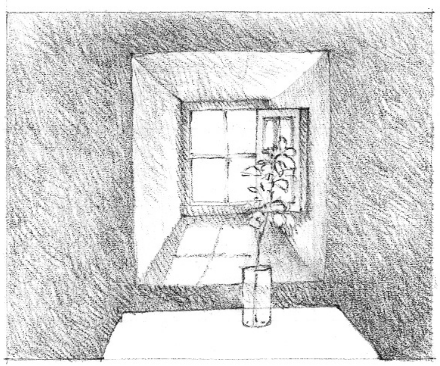


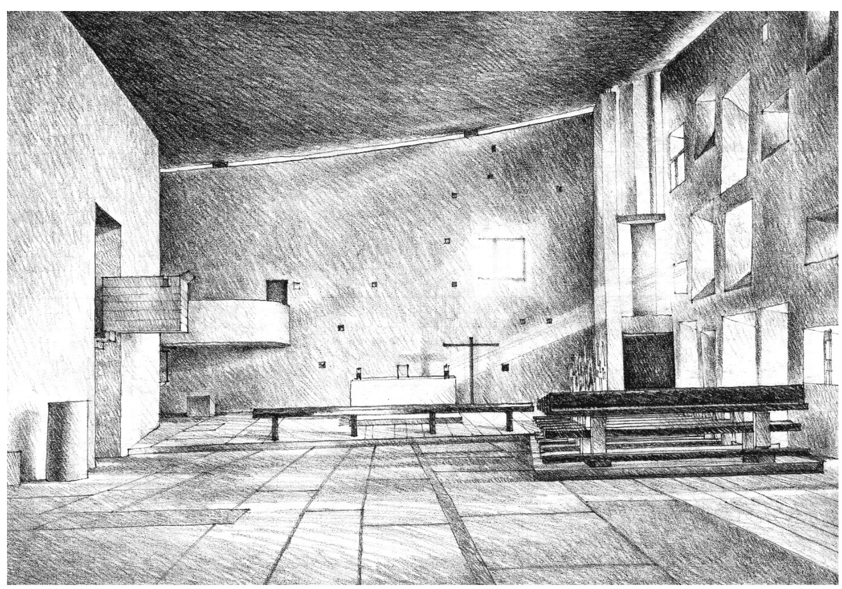
Skylight



An opening within a plane often appears as a bright figure on a contrasting field or background. If centered within the plane, the opening will appear stable and visually organize the surface around it. Moving the opening off-center will create a degree of visual tension between the opening and the edges of the plane toward which it is moved.



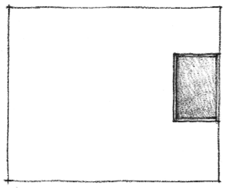




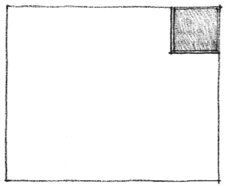
Chapel space, Notre Dame Du Haut, Ronchamp, France, 1950–1955, Le Corbusier

Openings at Corners

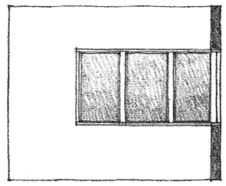
An opening can be located along one edge or at a corner of a wall or ceiling plane. In either case, the opening will be at a corner of a space.



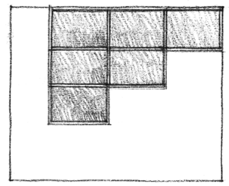
Along one edge



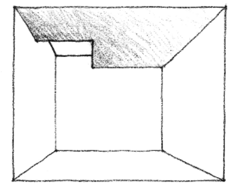
Along two edges



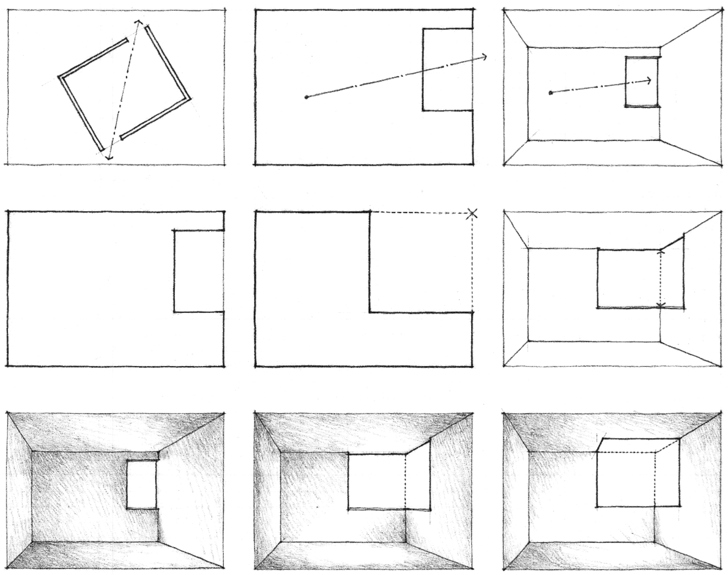
Turning a corner



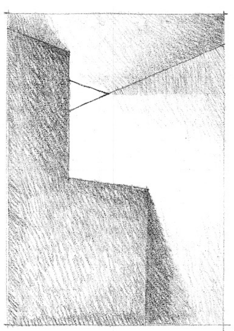
Grouped

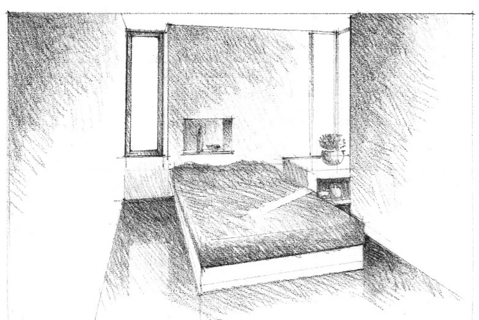


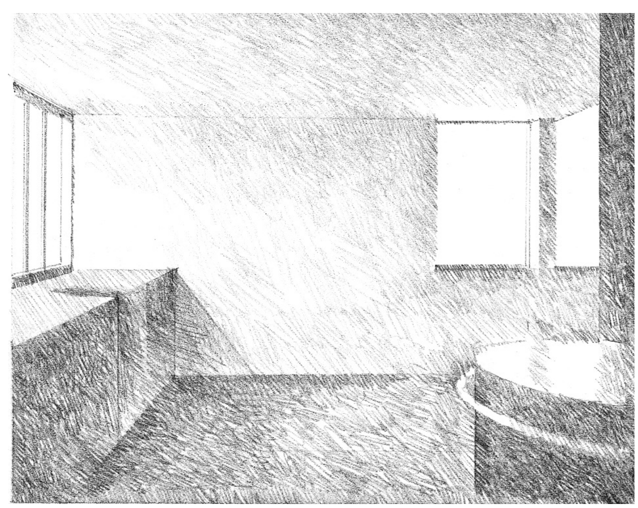
Skylight

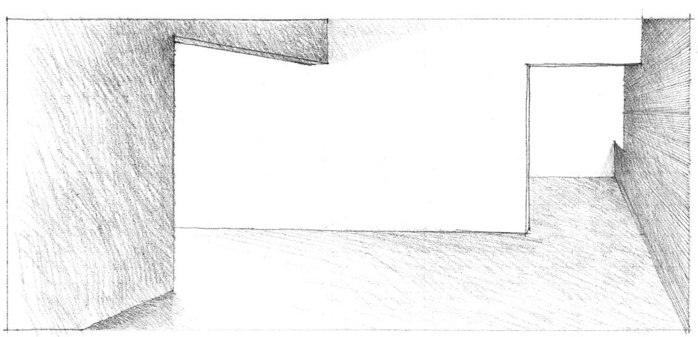


Openings that are located at corners give a space and the planes in which they are located a diagonal orientation. This directional effect may be desirable for compositional reasons, or the corner opening may be established to capture a desirable view or brighten a dark corner of a space.



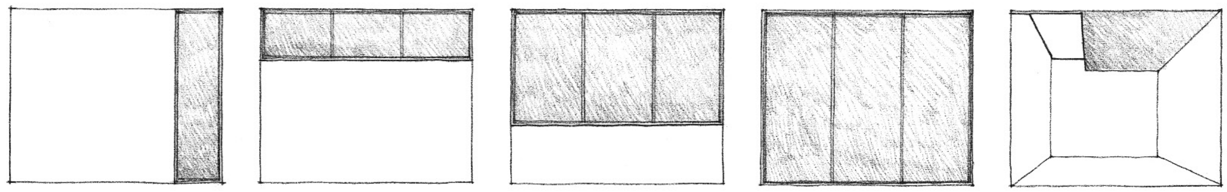




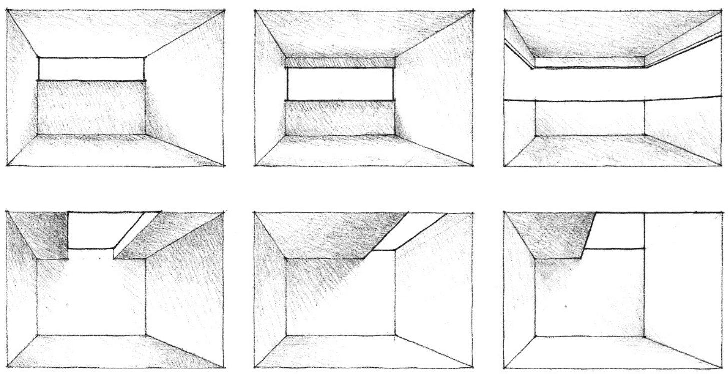


Openings between Planes

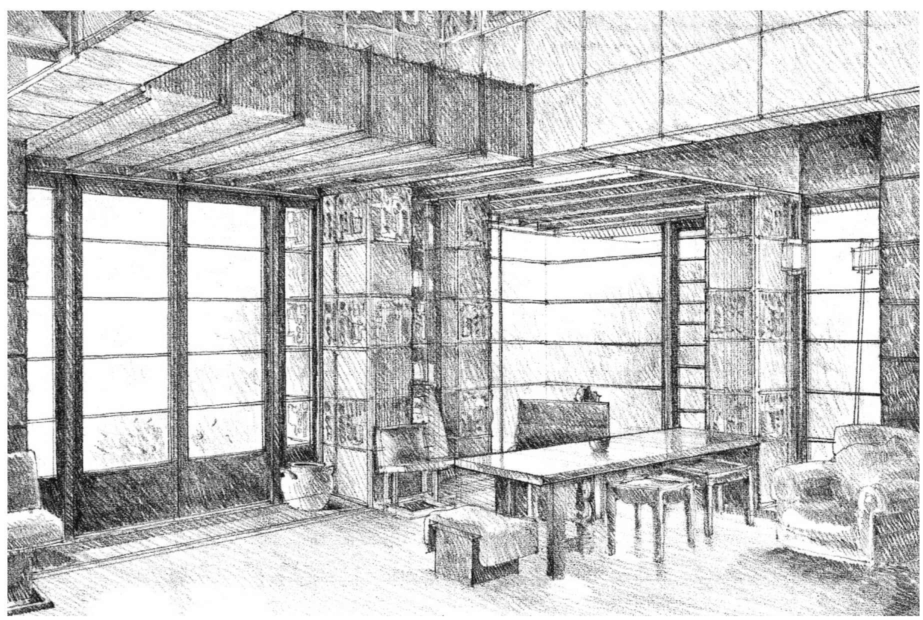
An opening can extend vertically between the floor and ceiling planes or horizontally between two wall planes. It can grow in size to occupy an entire wall of a space.



Vertical Horizontal $^{3}/_{4}$ opening Window-wall Skylight



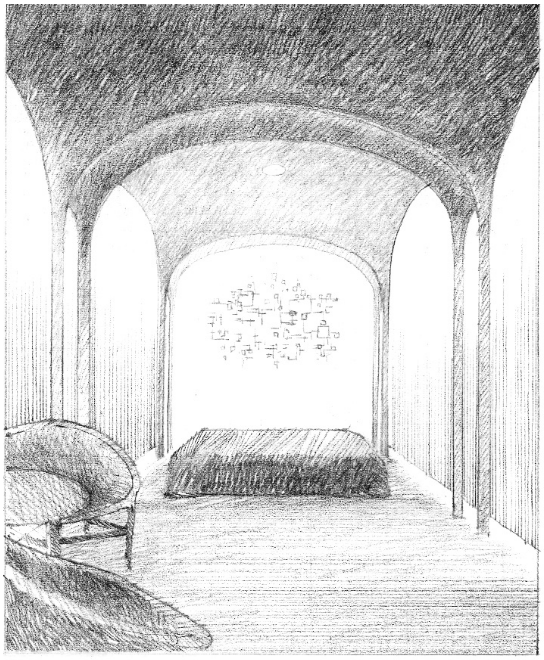
Openings that extend from the floor to the ceiling plane of a space visually separate and articulate the edges of adjacent wall planes.



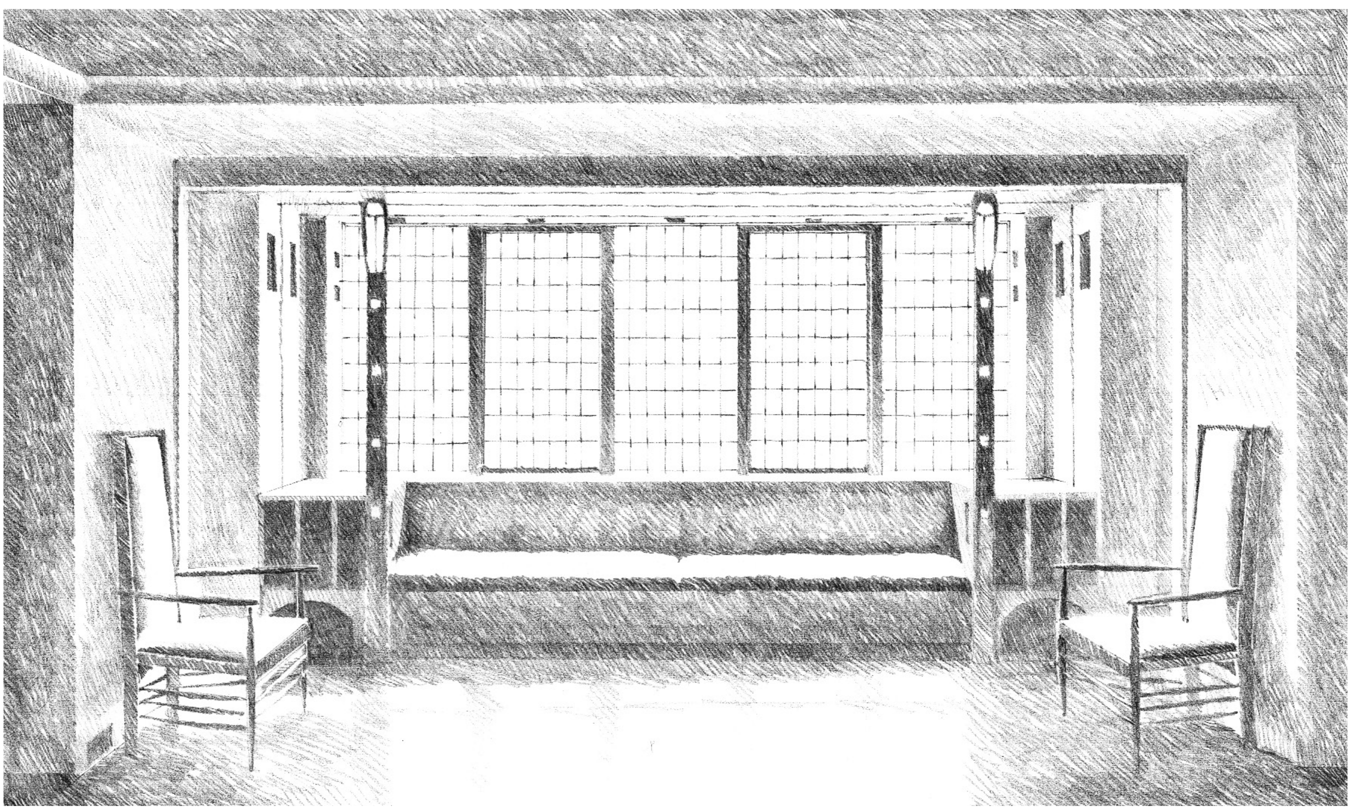
Living room, Samuel Freeman House, Los Angeles, California, 1924, Frank Lloyd Wright

Qualities of Architectural Space

The qualities of an architectural space are much richer than what diagrams are able to portray. The spatial qualities of form, proportion, scale, texture, light, and sound ultimately depend on the properties of the enclosure of a space. Our perception of these qualities is often a response to the combined effects of the properties encountered and is conditioned by culture, prior experiences, and personal interest or inclination.



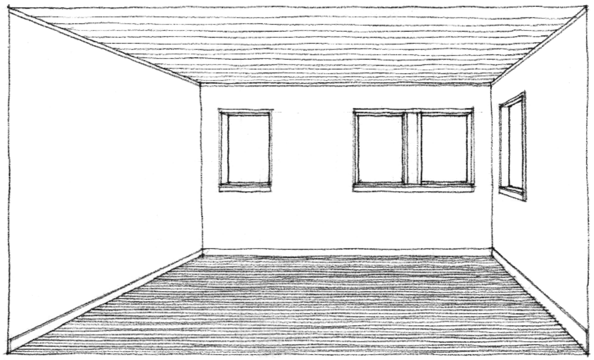
Bedroom in the Brick House, New Canaan, Connecticut, 1949, Philip Johnson

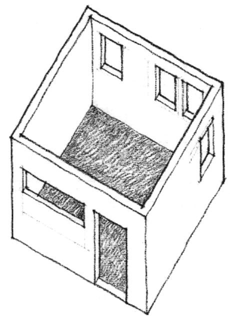


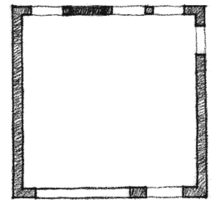
Bay window of the living room, Hill House, Helensburgh, Scotland, 1902–1903, Charles Rennie Mackintosh

Degree of Enclosure

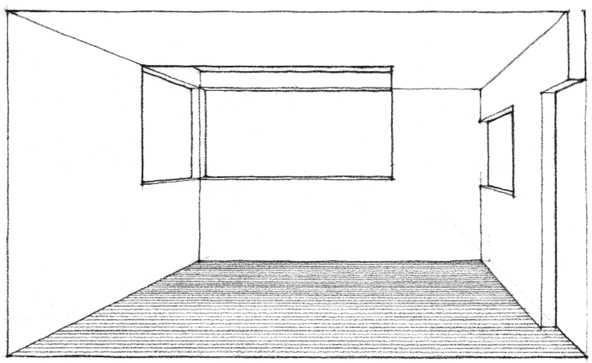
The degree of enclosure of a space, as determined by the configuration of its defining elements and the pattern of its openings, has a significant impact on our perception of its form and orientation. From within a space, we see only the surface of a wall. It is this thin layer of material that forms the vertical boundary of the space. The actual thickness of a wall plane can be revealed only along the edges of door and window openings.

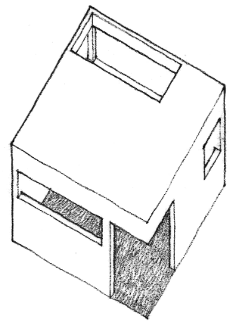


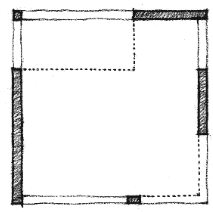




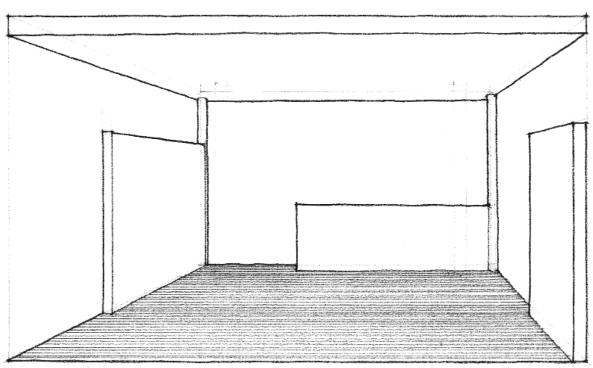
Openings lying wholly within the enclosing planes of a space do not weaken the edge definition nor the sense of closure of the space. The form of the space remains intact and perceptible.

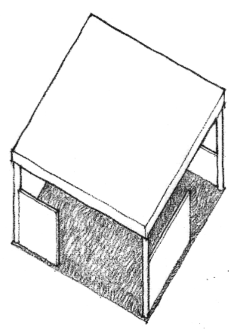


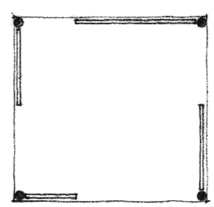




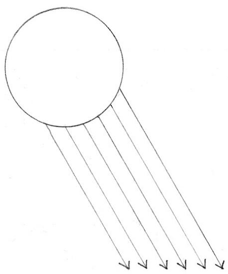
Openings located along the edges of the enclosing planes of a space visually weaken the corner boundaries of the volume. While these openings erode the overall form of a space, they also promote its visual continuity and interaction with adjacent spaces.





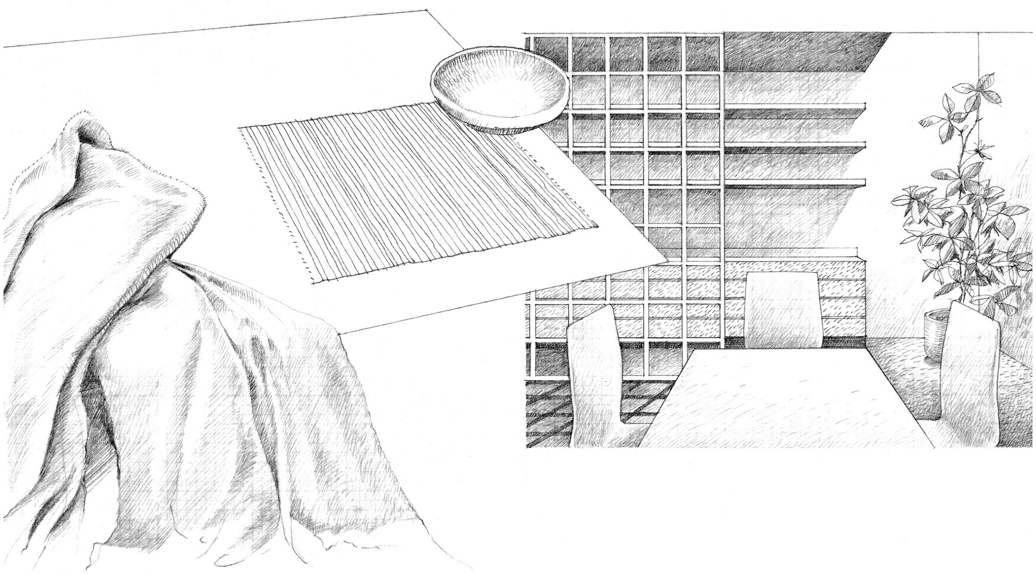


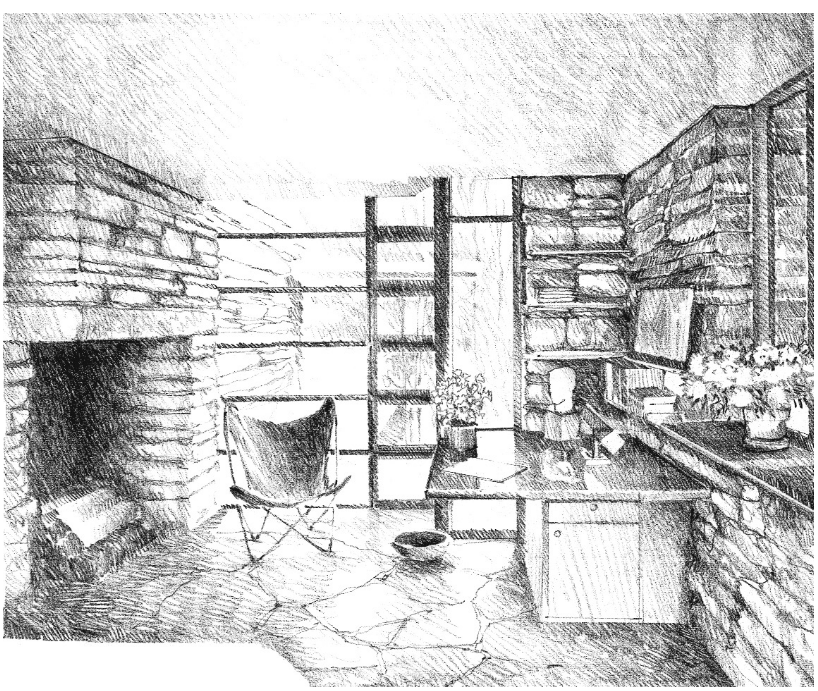
Openings between the enclosing planes of a space visually isolate the planes and articulate their individuality. As these openings increase in number and size, the space loses its sense of enclosure, becomes more diffuse, and begins to merge with adjacent spaces. The visual emphasis is on the enclosing planes rather than the volume of space defined by the planes.



Light

The sun is the rich source of natural light for the illumination of forms and spaces in architecture. While the sun's radiation is intense, the quality of its light, manifested in the form of direct sunlight or diffuse daylight, varies with the time of day, from season to season, and from place to place. As the luminous energy of the sun is dispersed by clouds, haze, and precipitation, it transmits the changing colors of the sky and the weather to the forms and surfaces it illuminates.

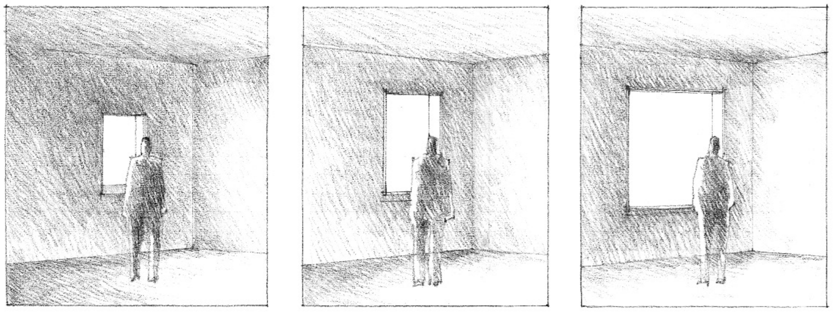




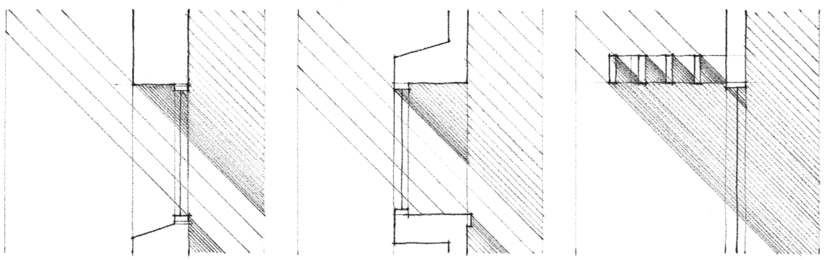
Penetrating a space through windows in a wall plane, or through skylights in the overhead roof plane, the radiant energy of the sun falls upon the surfaces within the room, enlivens their colors, and reveals their textures. With the shifting patterns of light, shade, and shadows that it creates, the sun animates the space of the room, and articulates the forms within it. By its intensity and dispersion within the room, the luminous energy of the sun can clarify the form of the space or distort it. The color and brilliance of sunlight can create a festive atmosphere within the room or a more diffuse daylight can instill within it a somber mood.

Since the intensity and direction of the light the sun radiates is fairly predictable, its visual impact on the surfaces, forms, and space of a room can be predicated on the size, location, and orientation of windows and skylights within the enclosure.

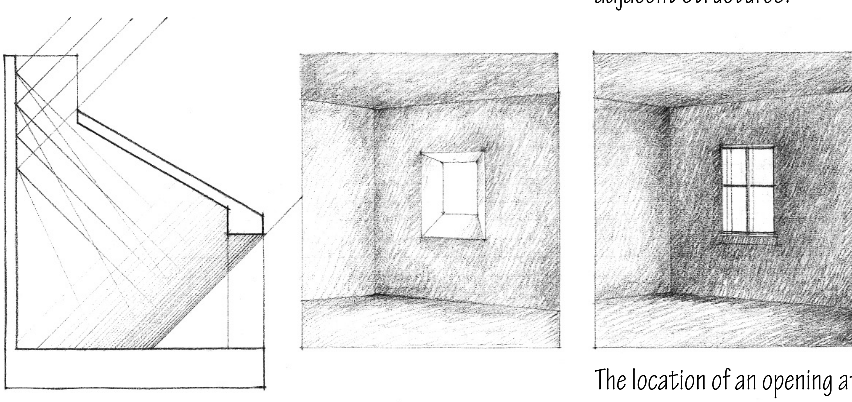
Fallingwater (Kaufmann House), Bear Run, Pennsylvania, 1936–1937, Frank Lloyd Wright



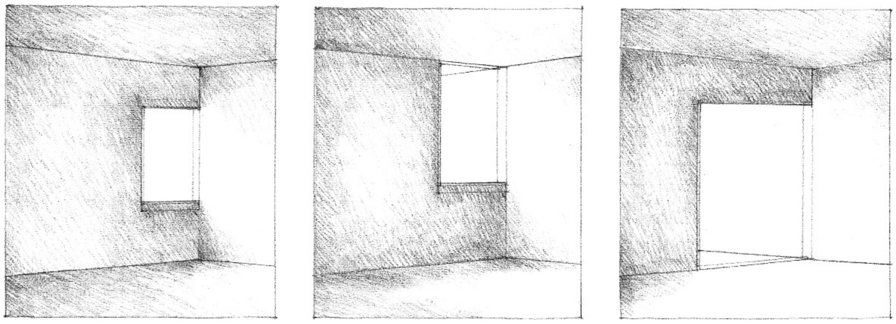
The size of a window or skylight controls the amount of daylight a room receives. The size of an opening in a wall or roof plane, however, is also regulated by factors other than light, such as the materials and construction of the wall or roof plane; requirements for views, visual privacy, and ventilation; the desired degree of enclosure for the space; and the effect of openings on the exterior form of a building. The location and orientation of a window or skylight, therefore, can be more important than its size in determining the quality of daylight a room receives.



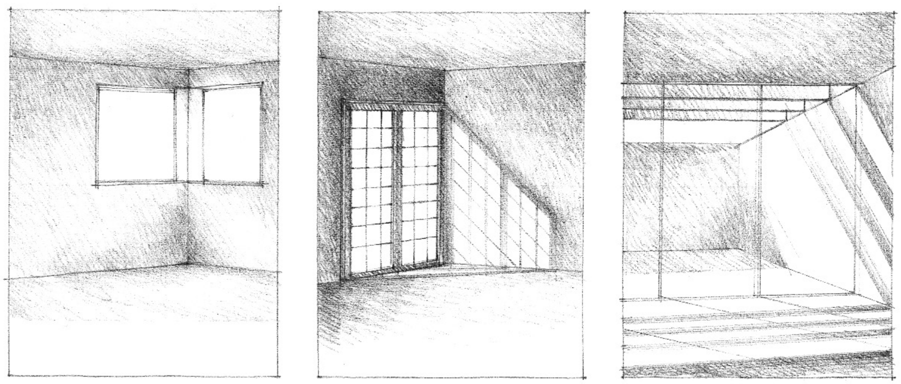
An opening can be oriented to receive direct sunlight during certain portions of the day. Direct sunlight provides a high degree of illumination that is especially intense during midday hours. It creates sharp patterns of light and dark on the surfaces of a room and crisply articulates the forms within the space. Possible detrimental effects of direct sunlight, such as glare and excessive heat gain, can be controlled by shading devices built into the form of the opening or provided by the foliage of nearby trees or adjacent structures.



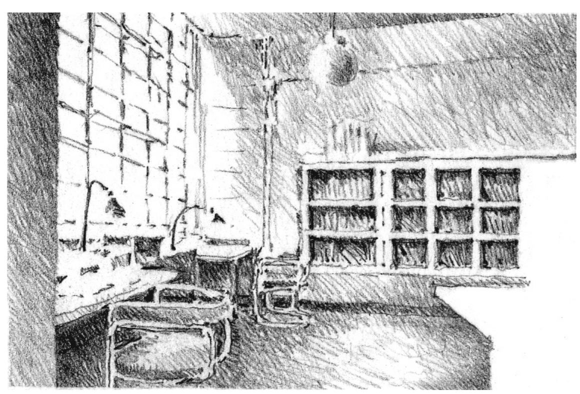
The location of an opening affects the manner in which natural light enters a room and illuminates its forms and surfaces. When located entirely within a wall plane, an opening can appear as a bright spot of light on a darker surface. This condition can induce glare if an excessive degree of contrast exists between the brightness of the opening and the darker surface surrounding it. The uncomfortable or debilitating glare caused by excessive brightness ratios between adjacent surfaces or areas in a room can be ameliorated by allowing daylight to enter the space from at least two directions.



When an opening is located along the edge of a wall or at the corner of a room, the daylight entering through it will wash the surface of the wall adjacent and perpendicular to the plane of the opening. This illuminated surface itself becomes a source of light and enhances the light level within the space.

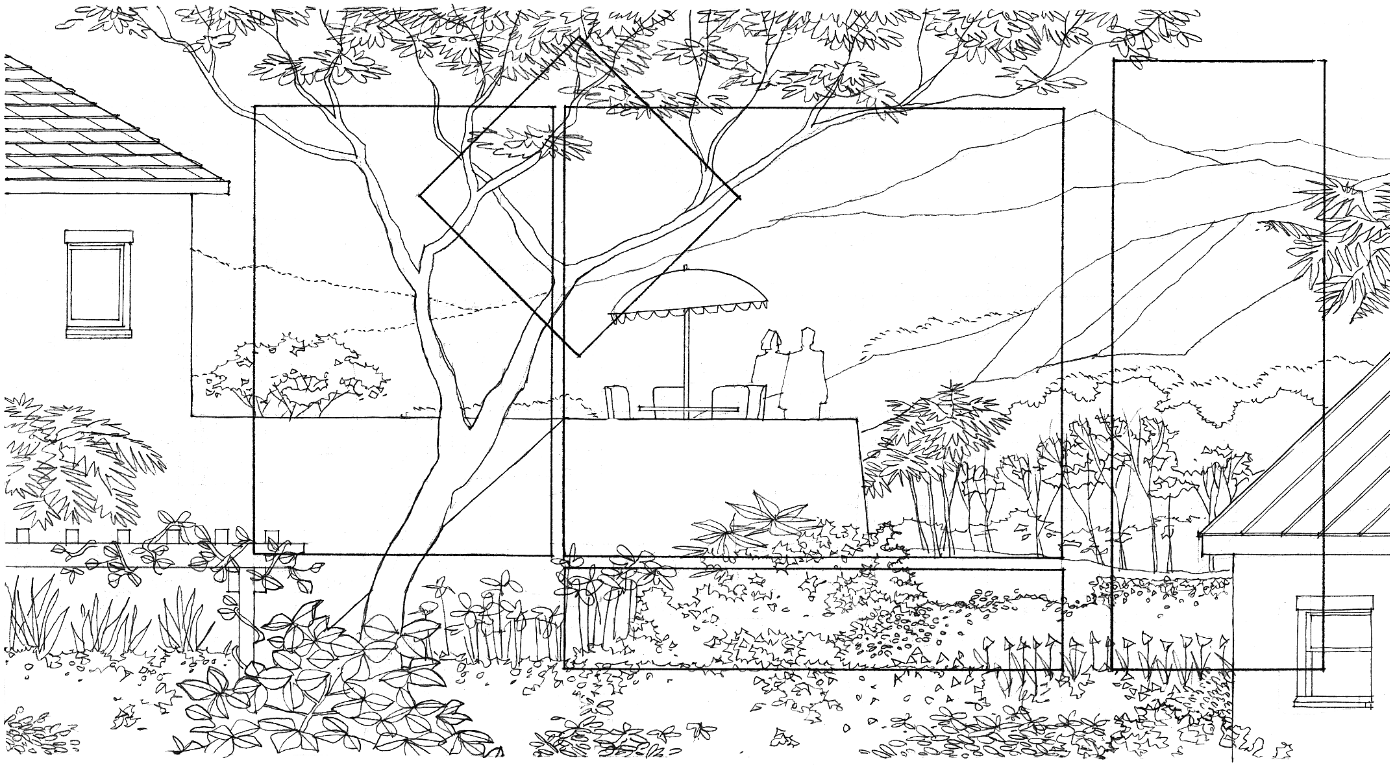


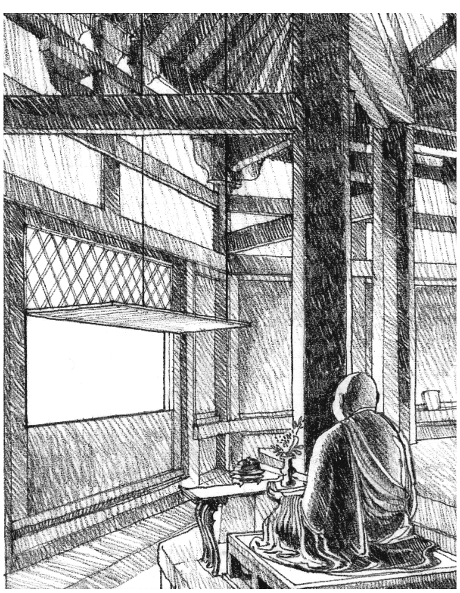
Additional factors influence the quality of light within a room. The shape and articulation of an opening is reflected in the shadow pattern cast by sunlight on the forms and surfaces of the room. The color and texture of these forms and surfaces, in turn, affect their reflectivity and the ambient light level within the space.



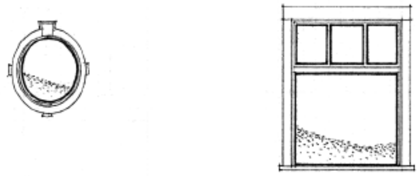
View

Another quality of space that must be considered in establishing openings in the enclosure of a room is its focus and orientation. While some rooms have an internal focus, such as a fireplace, others have an outward orientation given to them by a view to the outdoors or an adjacent space. Window and skylight openings provide this view and establish a visual relationship between a room and its surroundings. The size and location of these openings determine, of course, the nature of the outlook as well as the degree of visual privacy for an interior space.

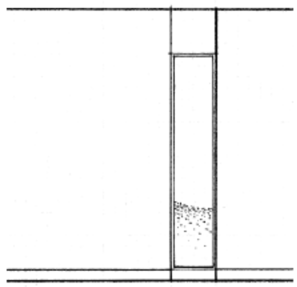




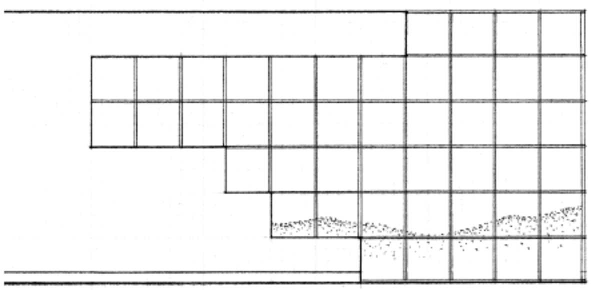
Outlook: interior of Horyu-Ji, Nara, Japan, seventh century CE. A window can be located such that a specific view can be seen from only one position in a room.



A small opening can reveal a close-up detail or frame a view so that we see it as a painting on a wall.

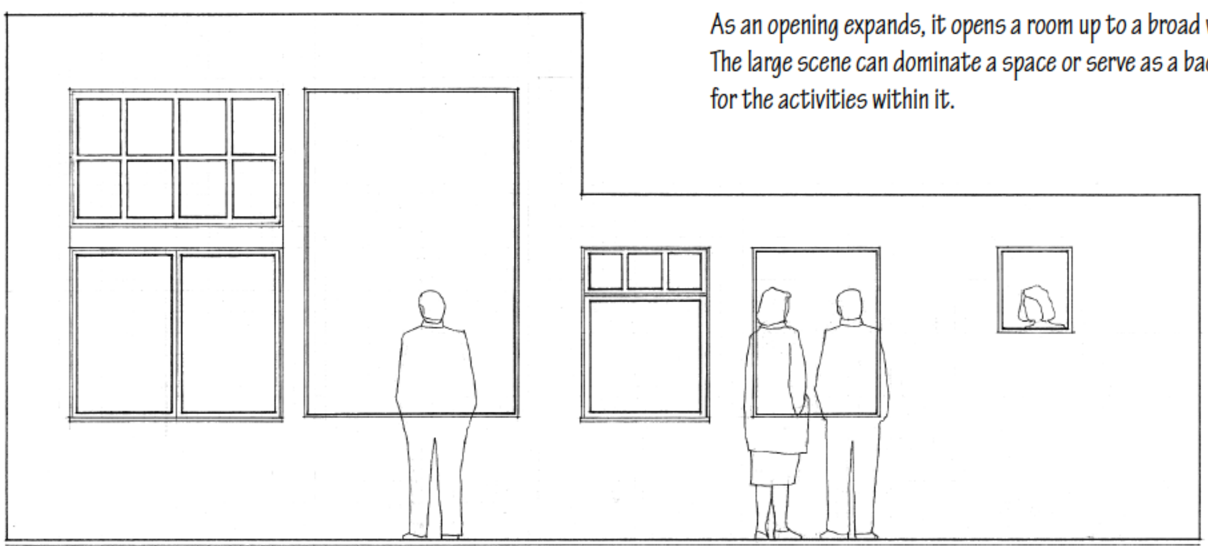


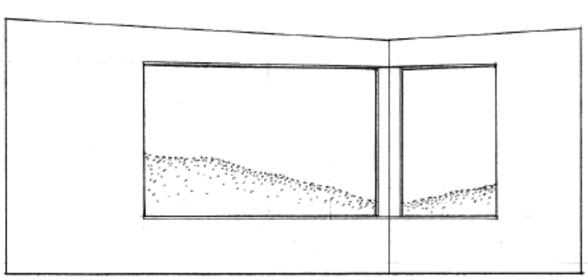
A long, narrow opening, whether vertical or horizontal, can not only separate two planes but also hint at what lies beyond.

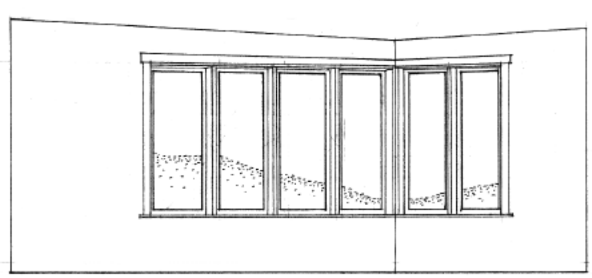


A group of windows can be sequenced to fragment a scene and encourage movement within a space.

As an opening expands, it opens a room up to a broad vista. The large scene can dominate a space or serve as a backdrop for the activities within it.

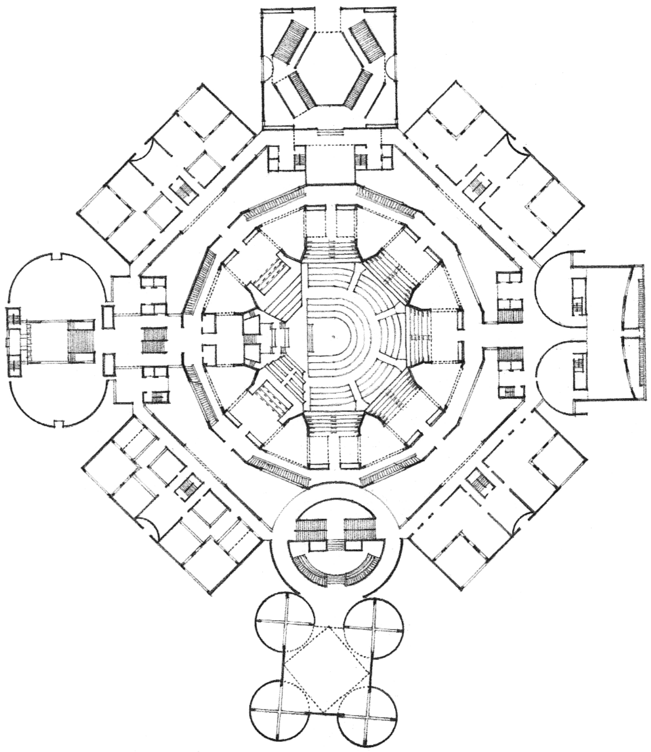






6 Fundamentals of Architecture:

Order



National Assembly Building, Capitol Complex at Dacca, Bangladesh, begun 1962, Louis Kahn

How Is Architecture Organized?

The various spaces and functions of a building are related to one another through principles of organization and ordering.

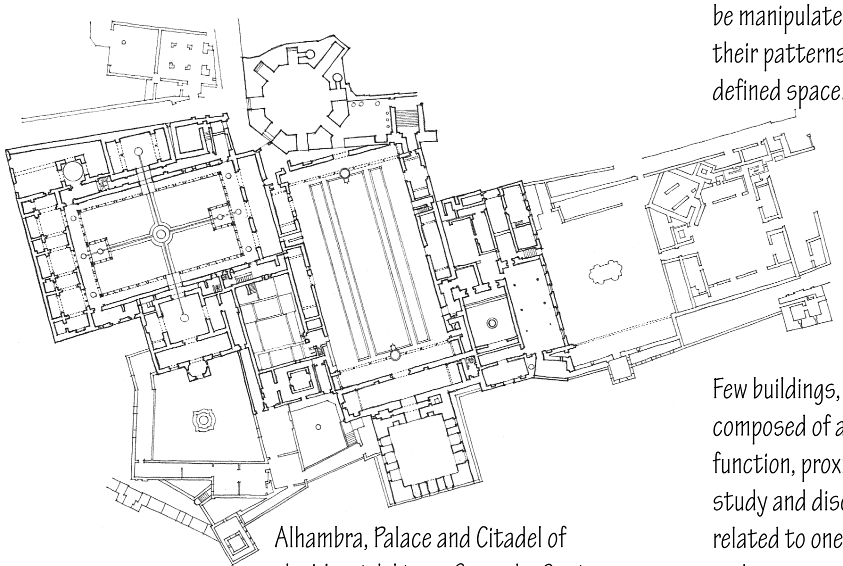
- Organizational principles determine which rooms are adjoining one another and which are separated. They determine the extent to which a space is public or private.
- Ordering principles determine the sequence in which areas are encountered. They define the logic by which spatial characteristics or functions are distributed throughout a building's composition.

These fundamental considerations of architectural design produce buildings that make sense—a building that is understood intuitively as one enters it. The arrangement and sequence of different spaces relative to one another will determine which ones are more or less important. The barriers that divide spaces and the openings that connect them tell a person which spaces should be entered, and which are off limits. The position of spaces near or far from one another determines the relationship between functions of the building.

This chapter discusses issues of design that pertain to the logical arrangement of spaces and forms in order to specifically define relationships between parts of a composition. It addresses organizational patterns as large-scale strategies for distributing parts of a composition. It addresses ordering logics that determine relationships between specific parts of a composition. It also addresses organizational elements—forms and assemblies that define or reinforce the relationships between components.

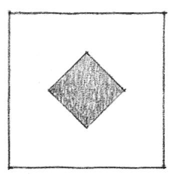
Organization of Form and Space

The last chapter laid out how various configurations of form could be manipulated to define a solitary field or volume of space, and how their patterns of solids and voids affected the visual qualities of the defined space.



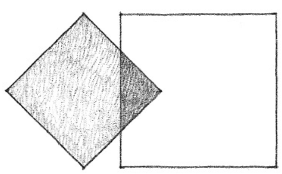
Alhambra, Palace and Citadel of the Moorish kings, Granada, Spain, 1248–1354

Few buildings, however, consist of a solitary space. They are normally composed of a number of spaces which are related to one another by function, proximity, or a path of movement. This chapter lays out for study and discussion the basic ways the spaces of a building can be related to one another and organized into coherent patterns of form and space.

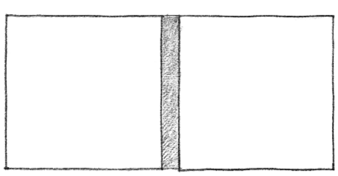


Two spaces may be related to each other in several fundamental ways.

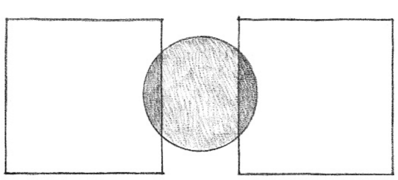
Space within a Space
A space may be contained within the volume of a larger space.



Interlocking Spaces
The field of a space may overlap the volume of another space.



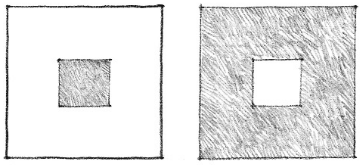
Adjacent Spaces
Two spaces may abut each other or share a common border.

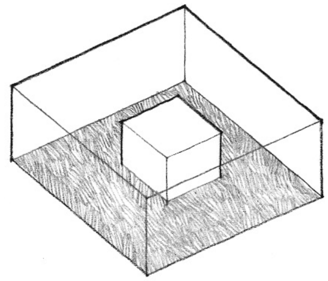


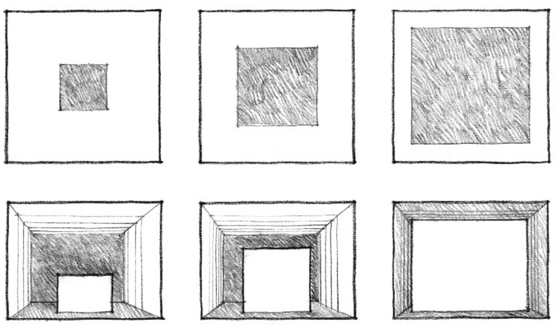
Spaces Linked by a Common Space
Two spaces may rely on an intermediary space for their relationship.

Space Within a Space

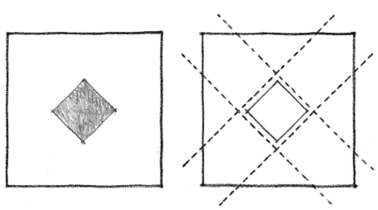
A large space can envelop and contain a smaller space within its volume. Visual and spatial continuity between the two spaces can be easily accommodated, but the smaller, contained space depends on the larger, enveloping space for its relationship to the exterior environment.

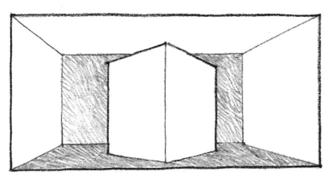




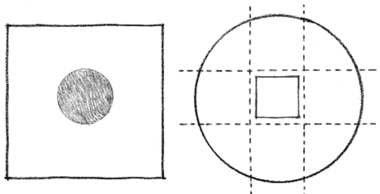


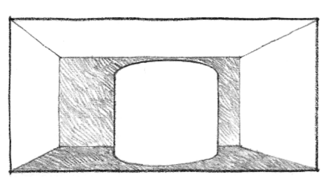
In this type of spatial relationship, the larger, enveloping space serves as a three-dimensional field for the smaller space contained within it. For this concept to be perceived, a clear differentiation in size is necessary between the two spaces. If the contained space were to increase in size, the larger space would begin to lose its impact as an enveloping form. If the contained space continued to grow, the residual space around it would become too compressed to serve as an enveloping space. It would become instead merely a thin layer or skin around the contained space. The original notion would be destroyed.





To endow itself with a higher attention value, the contained space may share the form of the enveloping shape, but be oriented in a different manner. This would create a secondary grid and a set of dynamic, residual spaces within the larger space.

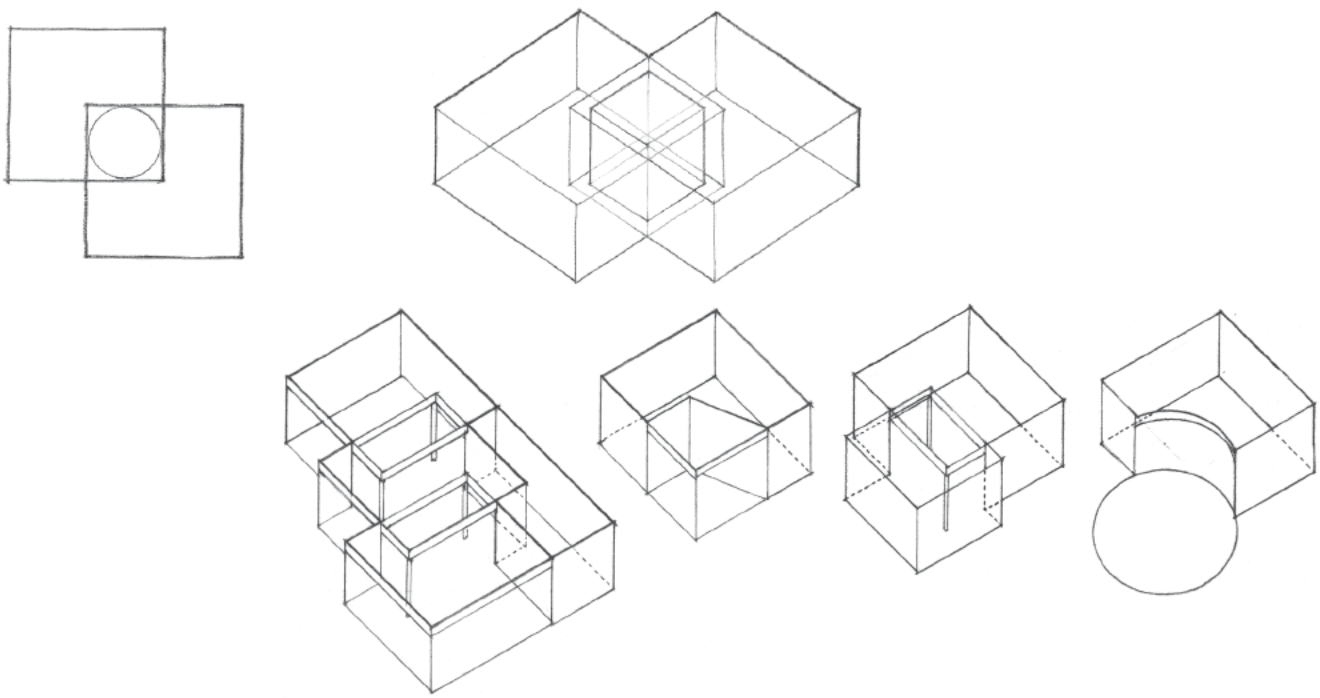


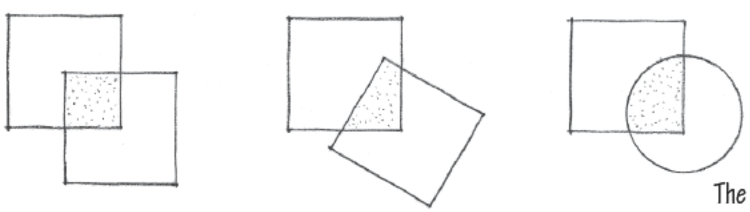


The contained space may also differ in form from the enveloping space in order to strengthen its image as a freestanding volume. This contrast in form may indicate a functional difference between the two spaces or the symbolic importance of the contained space.

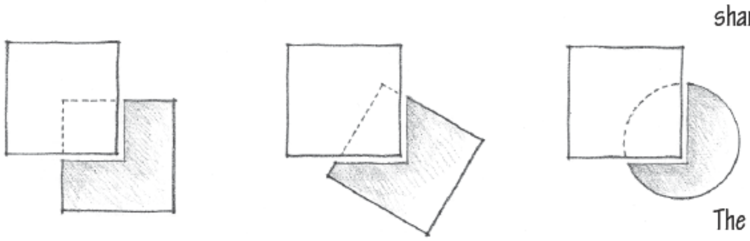
Interlocking Spaces

An interlocking spatial relationship results from the overlapping of two spatial fields and the emergence of a zone of shared space. When two spaces interlock their volumes in this manner, each retains its identity and definition as a space. However, the resulting configuration of the two interlocking spaces is subject to a number of interpretations.

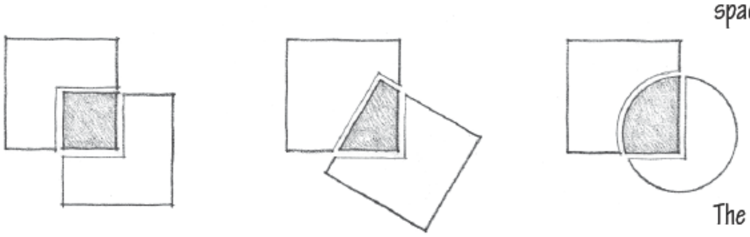




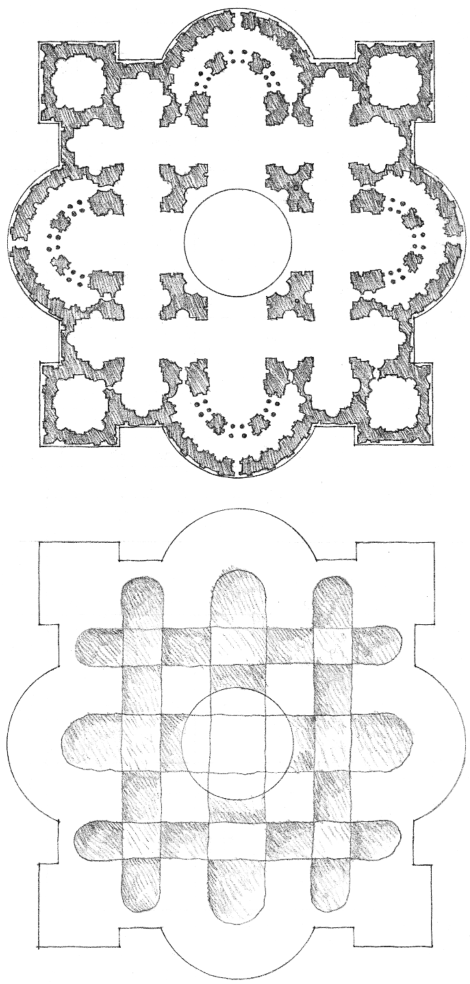
The interlocking portion of the two volumes can be shared equally by each space.



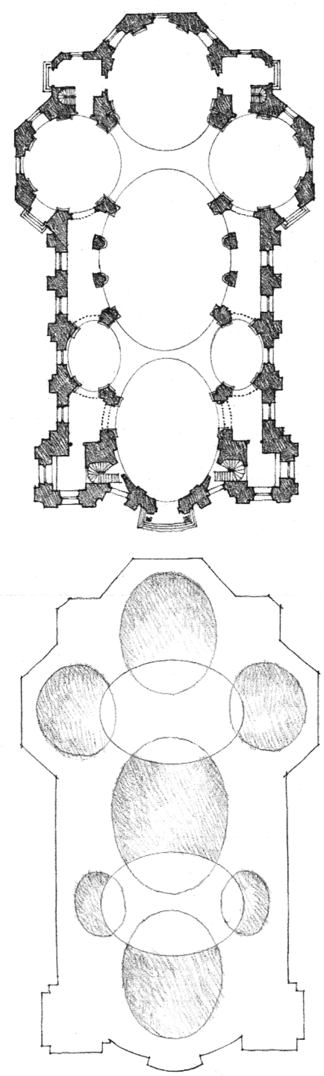
The interlocking portion can merge with one of the spaces and become an integral part of its volume.



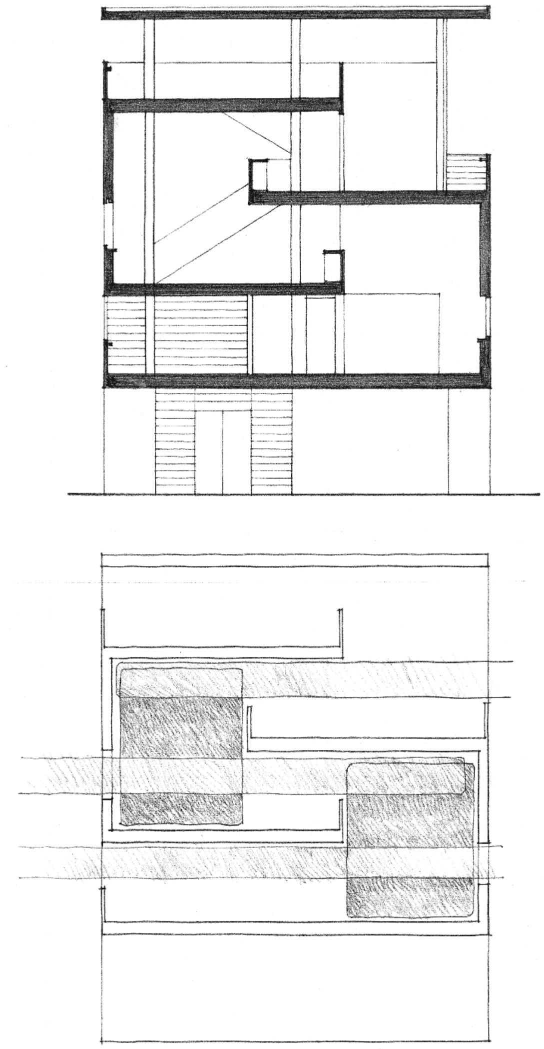
The interlocking portion can develop its own integrity as a space that serves to link the two original spaces.



Plan for St. Peter (Second Version), Rome, 1506–1520, Donato Bramante & Baldassare Peruzzi



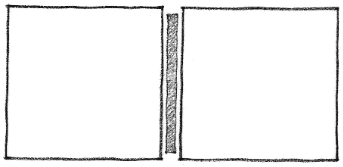
Pilgrimage Church, Vierzehnheiligen, Germany, 1744–1772, Balthasar Neumann

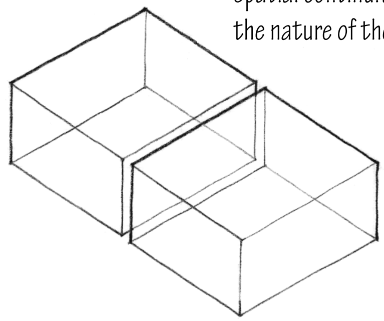


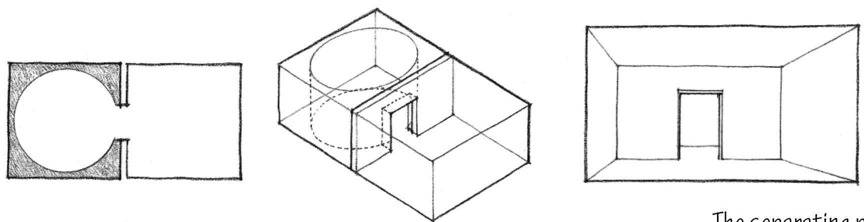
Villa at Carthage, Tunisia, 1928, Le Corbusier

Adjacent Spaces

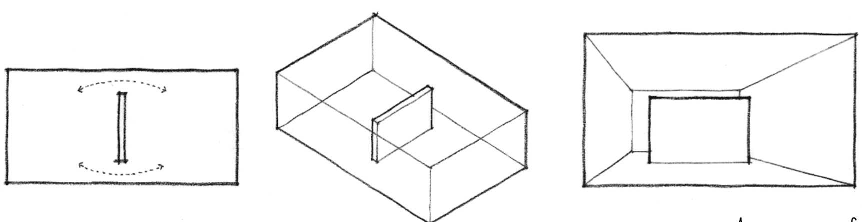
Adjacency is the most common type of spatial relationship. It allows each space to be clearly defined and to respond, each in its own way, to specific functional or symbolic requirements. The degree of visual and spatial continuity that occurs between two adjacent spaces depends on the nature of the plane that both separates and binds them together.



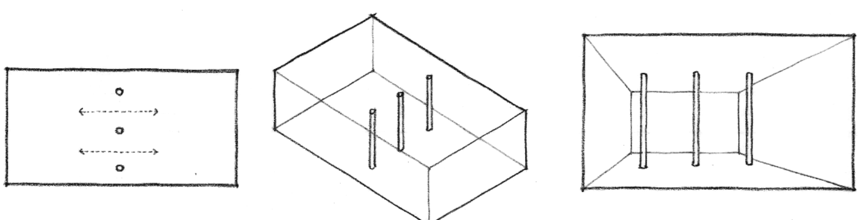




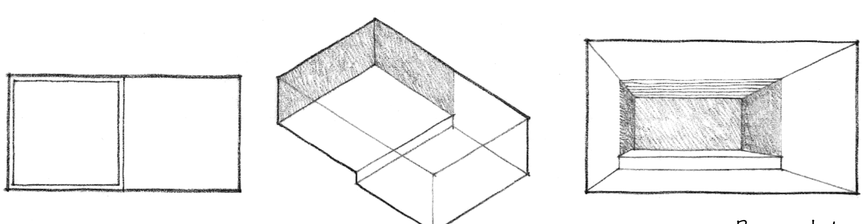
The separating plane may
- Limit visual and physical access between two adjacent spaces, reinforce the individuality of each space, and accommodate their differences;



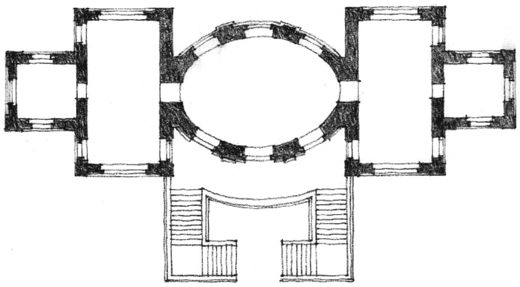
- Appear as a freestanding plane in a single volume of space;



- Be defined with a row of columns that allows a high degree of visual and spatial continuity between the two spaces;

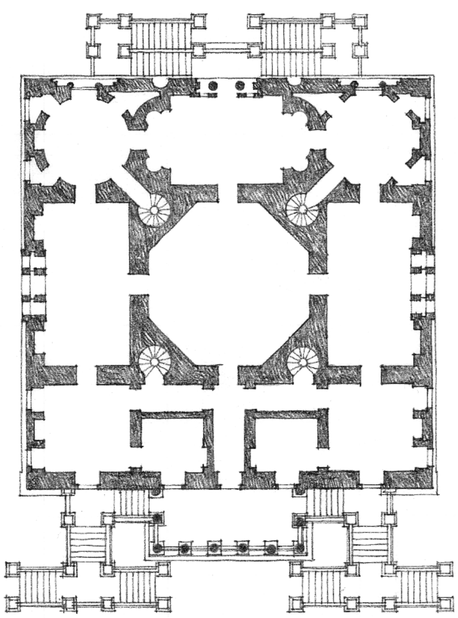


- Be merely implied with a change in level or a contrast in surface material or texture between the two spaces; this and the preceding two cases can also be read as single volumes of space which are divided into two related zones.

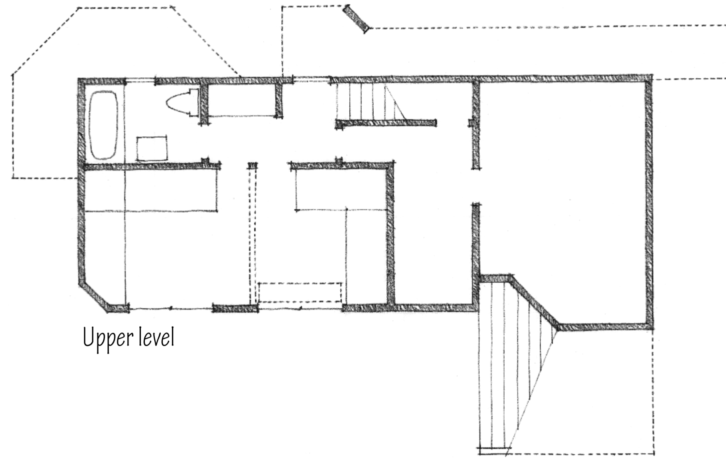


Pavilion Design, seventeenth century, Fischer von Erlach

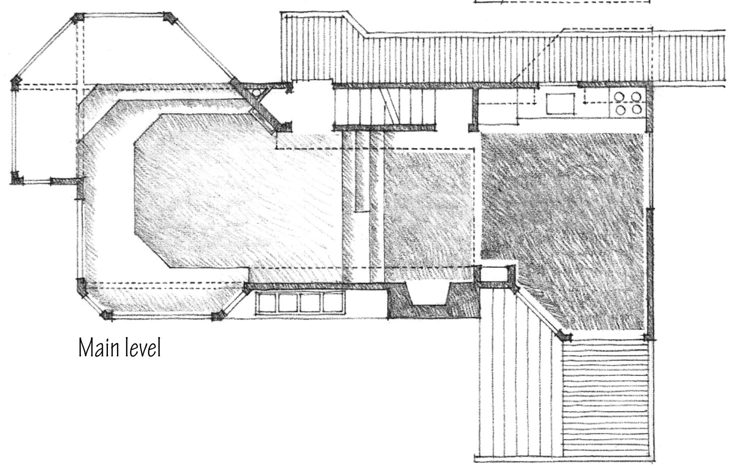
The spaces in these two buildings are individual in size, shape, and form. The walls that enclose them adapt their forms to accommodate the differences between adjacent spaces.



Chiswick House, Chiswick, England, 1729, Lord Burlington and William Kent

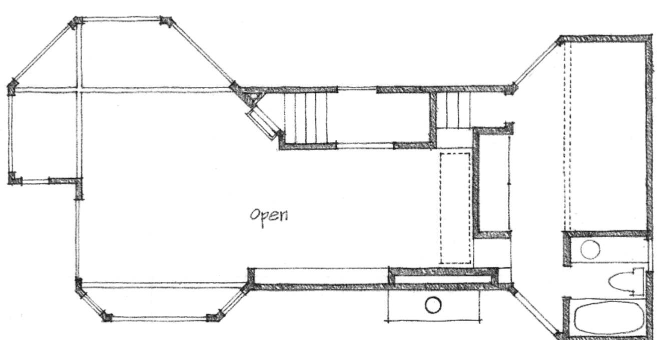


Upper level



Main level

Three spaces—the living, fireplace, and dining areas—are defined by changes in floor level, ceiling height, and quality of light and view, rather than by wall planes.

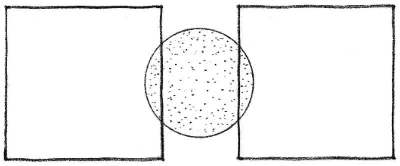


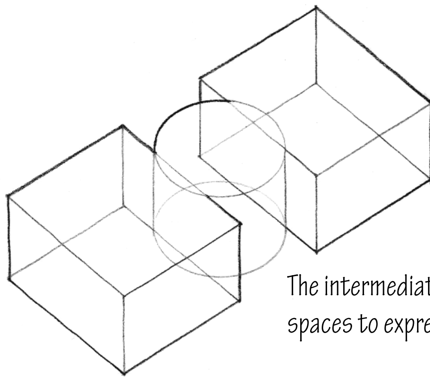
Lower level

Lawrence House, Sea Ranch, California, 1966, Moore-Turnbull/MLTW

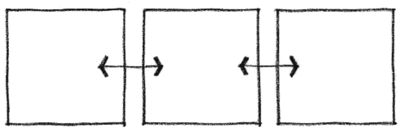
Spaces Linked by a Common Space

Two spaces that are separated by distance can be linked or related to each other by a third, intermediate, space. The visual and spatial relationship between the two spaces depends on the nature of the third space with which they share a common bond.

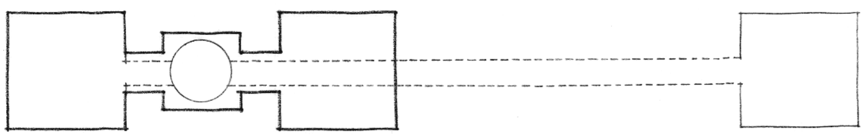




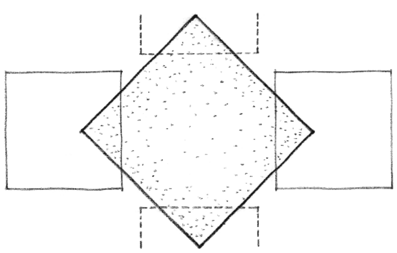
The intermediate space can differ in form and orientation from the two spaces to express its linking function.



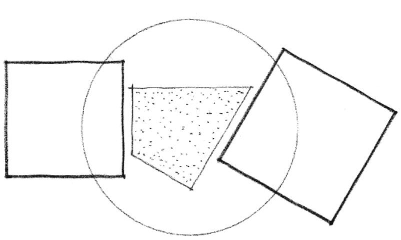
The two spaces, as well as the intermediate space, can be equivalent in size and shape and form a linear sequence of spaces.



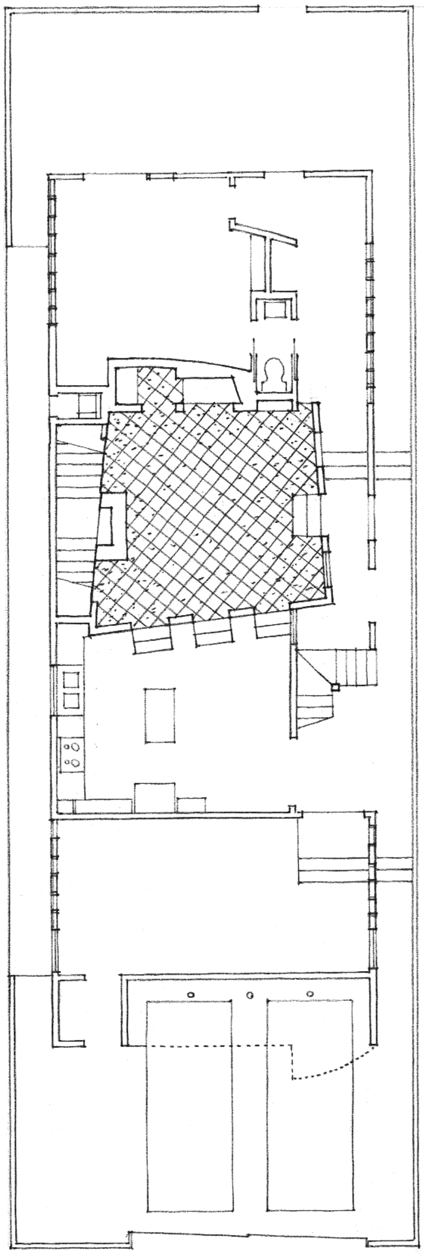
The intermediate space can itself become linear in form to link two spaces that are distant from each other, or join a whole series of spaces that have no direct relationship to one another.



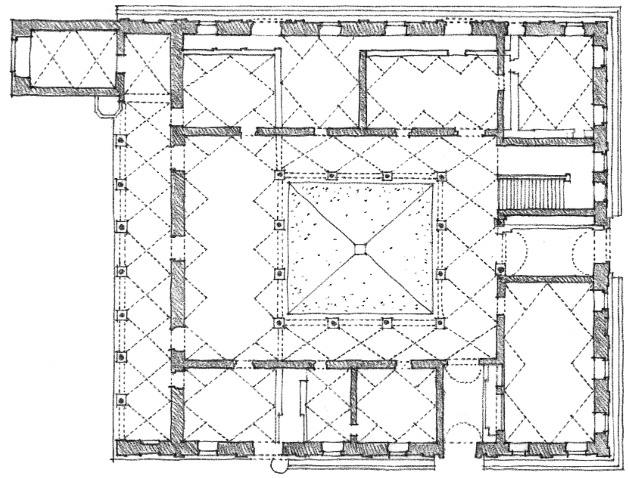
The intermediate space can, if large enough, become the dominant space in the relationship, and be capable of organizing a number of spaces about itself.



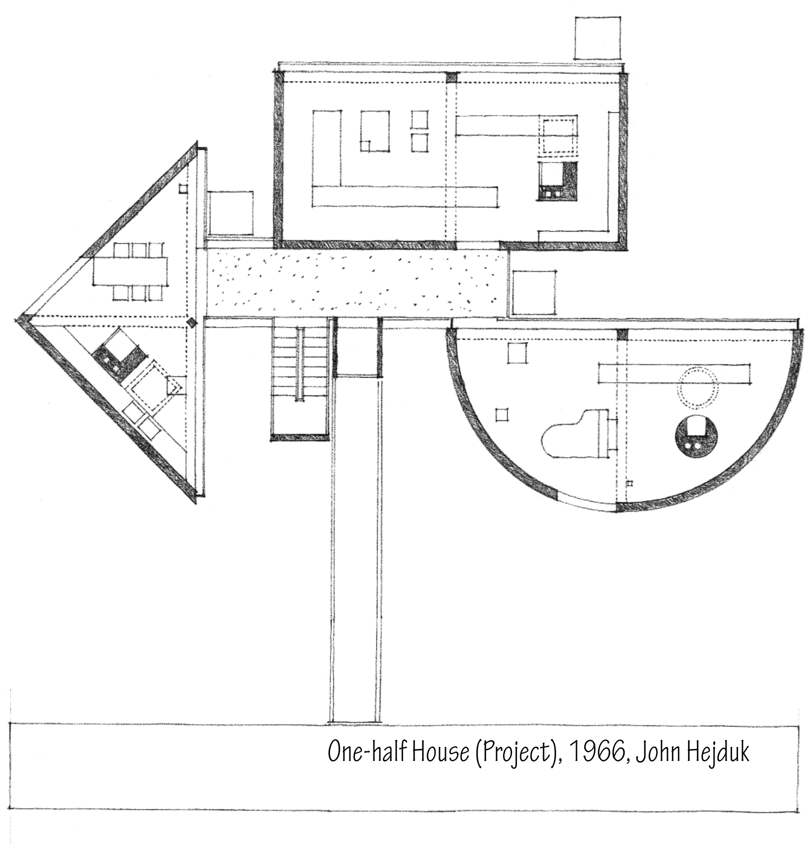
The form of the intermediate space can be residual in nature and be determined solely by the forms and orientations of the two spaces being linked.



Caplin House, Venice, California, 1979, Frederick Fisher



Palazzo Piccolomini, Pienza, Italy, c. 1460, Bernardo Rosselino

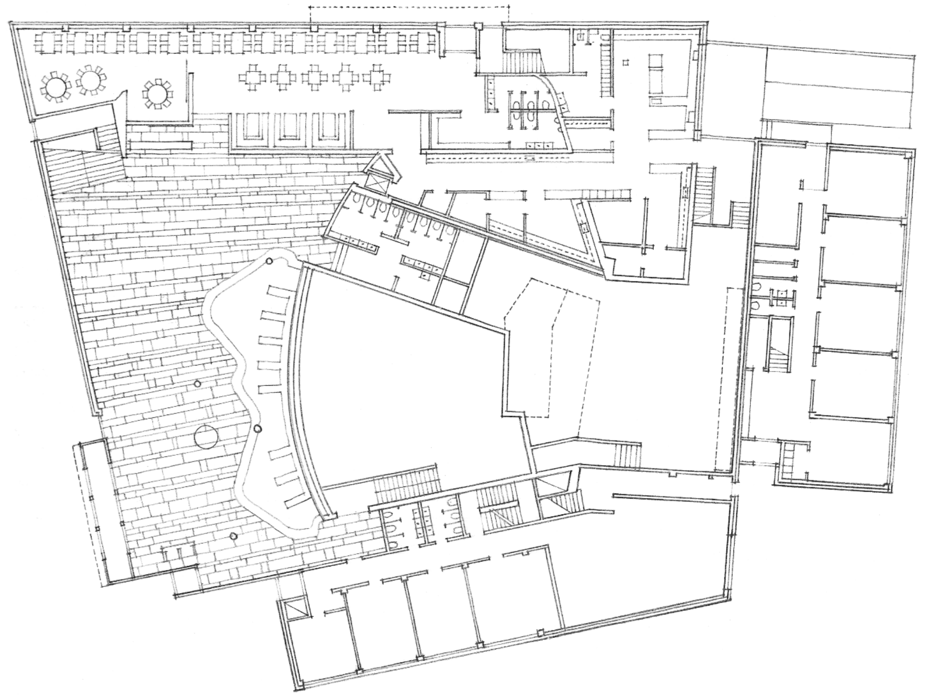


One-half House (Project), 1966, John Hejduk

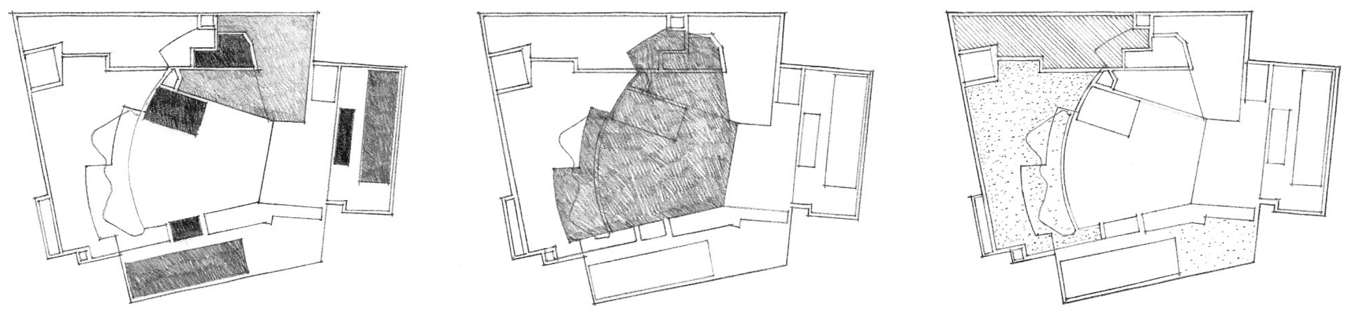
Spatial Organizations

The following section lays out the basic ways we can arrange and organize the spaces of a building. In a typical building program, there are usually requirements for various kinds of spaces. There may be requirements for spaces that:

- Have specific functions or require specific forms
- Are flexible in use and can be freely manipulated
- Are singular and unique in their function or significance to the building organization
- Have similar functions and can be grouped into a functional cluster or repeated in a linear sequence
- Require exterior exposure for light, ventilation, outlook, or access to outdoor spaces
- Must be segregated for privacy
- Must be easily accessible



Theater at Seinäjoki, Finland, 1968–1969, Alvar Aalto



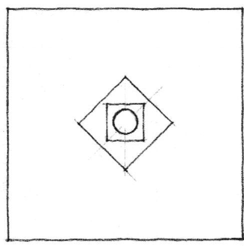
Analytical diagrams of fixed and flexible types of spaces in the Theater at Seinäjoki

The manner in which these spaces are arranged can clarify their relative importance and functional or symbolic role in the organization of a building. The decision as to what type of organization to use in a specific situation will depend on:

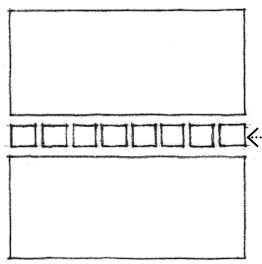
- The demands of the building program, such as functional proximities, dimensional requirements, hierarchical classification of spaces, and requirements for access, light, or view
- Exterior conditions of the site that might limit the organization's form or growth, or that might encourage the organization to address certain features of its site and turn away from others

Each type of spatial organization is introduced by a section that discusses the formal characteristics, spatial relationships, and contextual responses of the category. A range of examples then illustrates the basic points made in the introduction. Each of the examples should be studied in terms of:

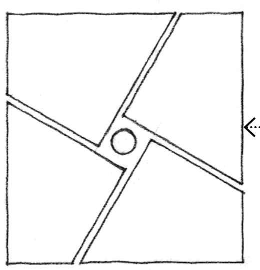
- What kinds of spaces are accommodated and where? How are they defined?
- What kinds of relationships are established among the spaces, one to another, and to the exterior environment?
- Where can the organization be entered, and what configuration does the path of circulation have?
- What is the exterior form of the organization, and how might it respond to its context?



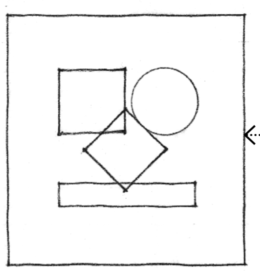
Centralized Organization
A central, dominant space about which a number of secondary spaces are grouped



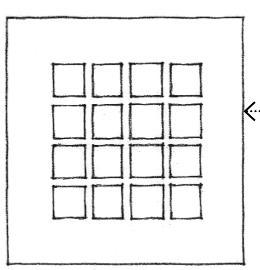
Linear Organization
A linear sequence of repetitive spaces



Radial Organization
A central space from which linear organizations of space extend in a radial manner



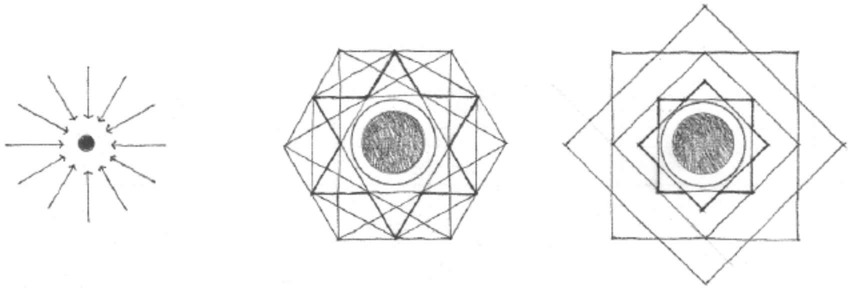
Clustered Organization
Spaces grouped by proximity or the sharing of a common visual trait or relationship

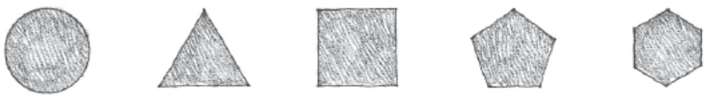


Grid Organization
Spaces organized within the field of a structural grid or other three-dimensional framework

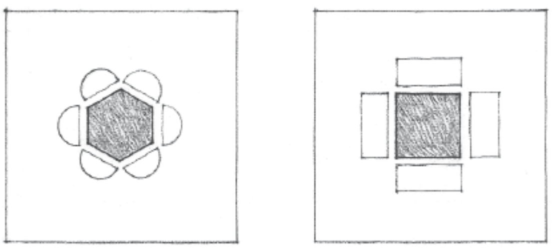
Centralized Organizations

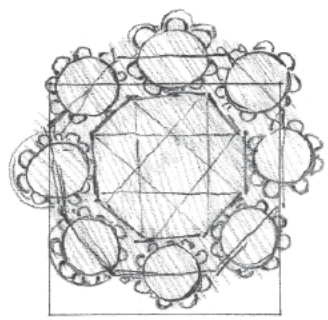
A centralized organization is a stable, concentrated composition that consists of a number of secondary spaces grouped around a large, dominant, central space.





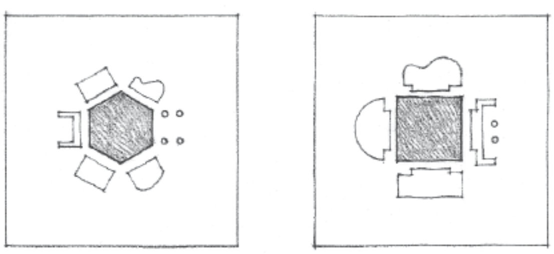
The central, unifying space of the organization is generally regular in form and large enough in size to gather a number of secondary spaces about its perimeter.

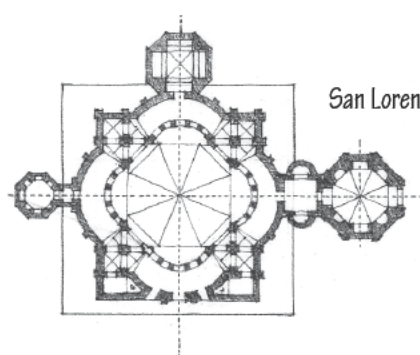




Ideal Church by Leonardo Da Vinci

The secondary spaces of the organization may be equivalent to one another in function, form, and size, and create an overall configuration that is geometrically regular and symmetrical about two or more axes.

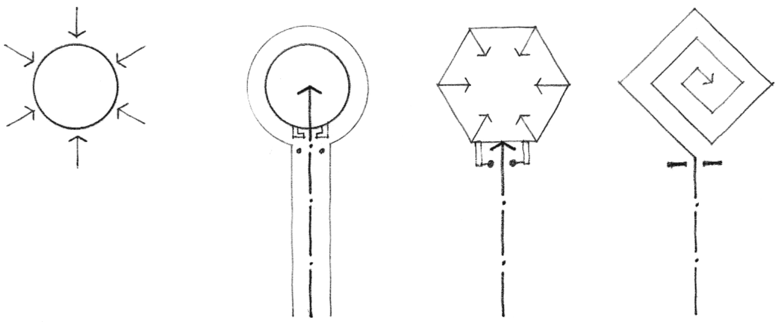




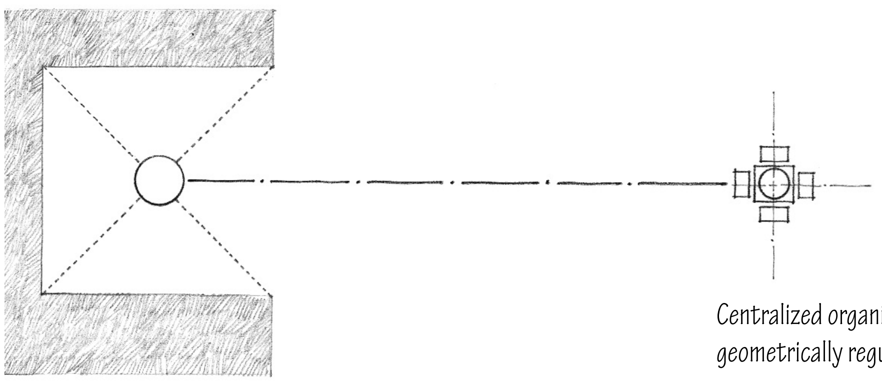
San Lorenzo Maggiore, Milan, Italy, c. 480 CE

The secondary spaces may differ from one another in form or size in order to respond to individual requirements of function, express their relative importance, or acknowledge their surroundings. This differentiation among the secondary spaces also allows the form of a centralized organization to respond to the environmental conditions of its site.

Since the form of a centralized organization is inherently nondirectional, conditions of approach and entry must be specified by the site and the articulation of one of the secondary spaces as an entrance or gateway.

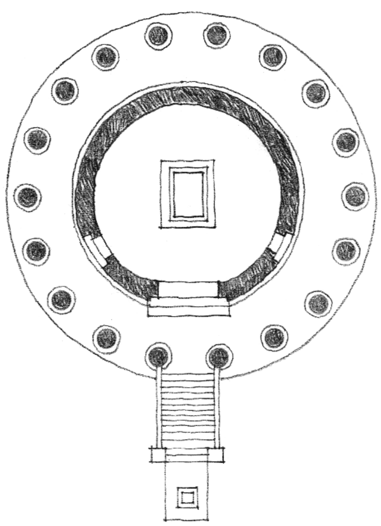


The pattern of circulation and movement within a centralized organization may be radial, loop, or spiral in form. In almost every case, however, the pattern will terminate in or around the central space.



Centralized organizations whose forms are relatively compact and geometrically regular can be used to:

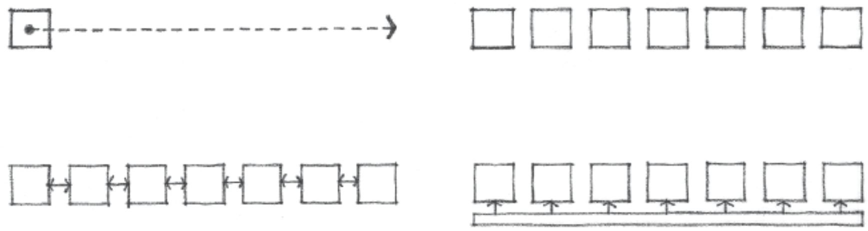
- Establish points or places in space
- Terminate axial conditions
- Serve as an object-form within a defined field or volume of space



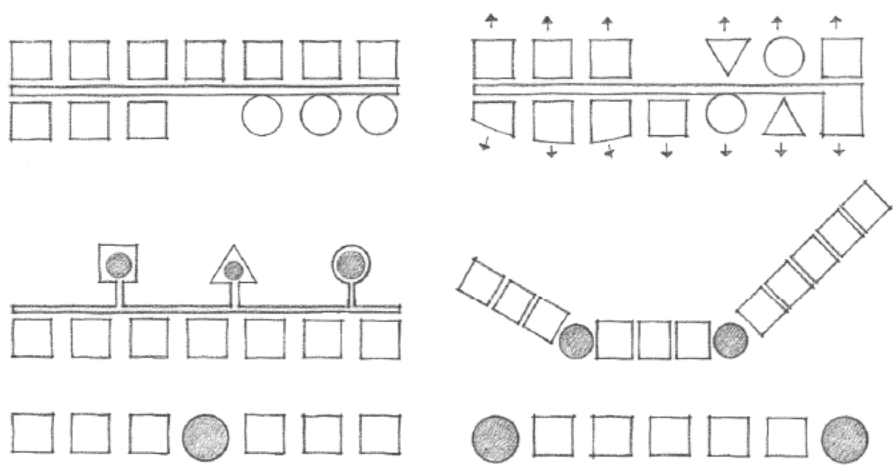
- The central organizing space may be either an interior or an exterior space.

Linear Organizations

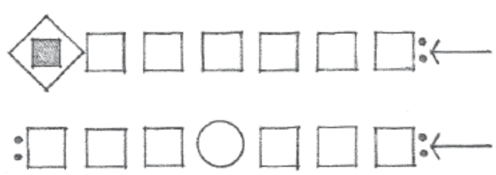
A linear organization consists essentially of a series of spaces. These spaces can either be directly related to one another or be linked through a separate and distinct linear space.



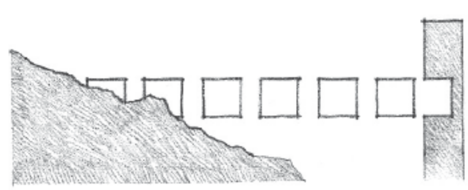
A linear organization usually consists of repetitive spaces that are alike in size, form, and function. It may also consist of a single linear space that organizes along its length a series of spaces that differ in size, form, or function. In both cases, each space along the sequence has an exterior exposure.



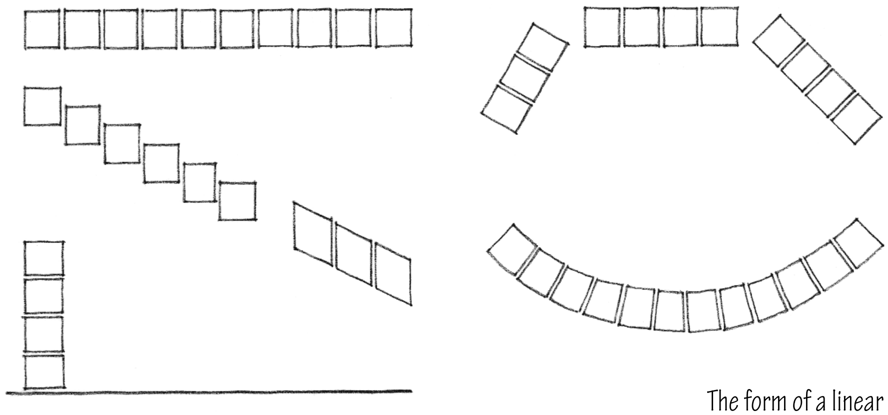
Spaces that are functionally or symbolically important to the organization can occur anywhere along the linear sequence and have their importance articulated by their size and form. Their significance can also be emphasized by their location:



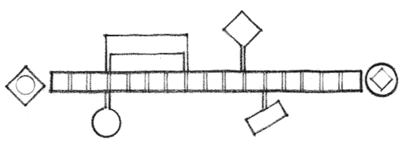
- At the end of the linear sequence
- Offset from the linear organization
- At pivotal points of a segmented linear form

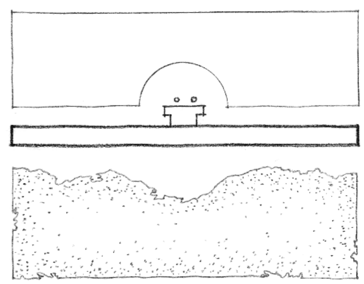


Because of their characteristic length, linear organizations express a direction and signify movement, extension, and growth. To limit their growth, linear organizations can be terminated by a dominant space or form, by an elaborate or articulated entrance, or by merging with another building form or the topography of its site.



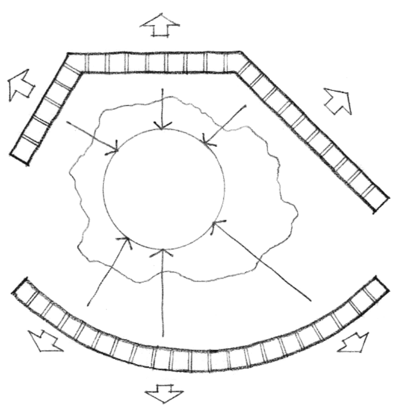
The form of a linear organization is inherently flexible and can respond readily to various conditions of its site. It can adapt to changes in topography, maneuver around a body of water or a stand of trees, or turn to orient spaces to capture sunlight and views. It can be straight, segmented, or curvilinear. It can run horizontally across its site, run diagonally up a slope, or stand vertically as a tower.





The form of a linear organization can relate to other forms in its context by:

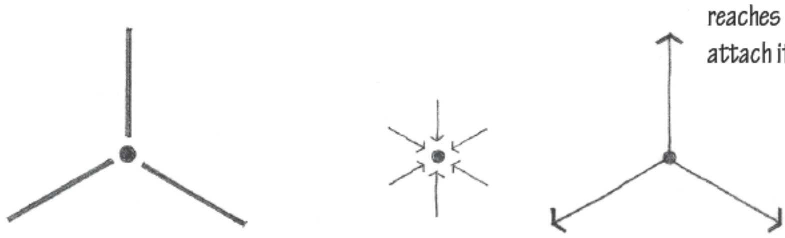
- Linking and organizing them along its length
- Serving as a wall or barrier to separate them into different fields
- Surrounding and enclosing them within a field of space



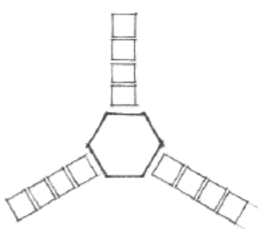
Curved and segmented forms of linear organizations enclose a field of exterior space on their concave sides and orient their spaces toward the center of the field. On their concave sides, these forms appear to front space and exclude it from their fields.

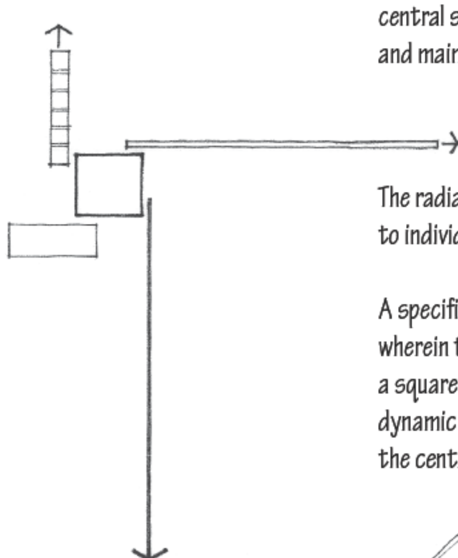
Radial Organizations

A radial organization of space combines elements of both centralized and linear organizations. It consists of a dominant central space from which a number of linear organizations extend in a radial manner. Whereas a centralized organization is an introverted scheme that focuses inward on its central space, a radial organization is an extroverted plan that reaches out to its context. With its linear arms, it can extend and attach itself to specific elements or features of its site.



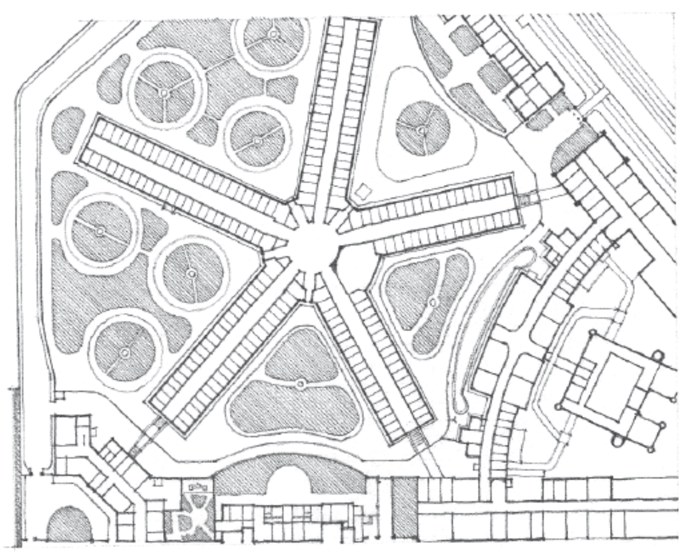
As with centralized organizations, the central space of a radial organization is generally regular in form. The linear arms, for which the central space is the hub, may be similar to one another in form and length and maintain the regularity of the organization's overall form.



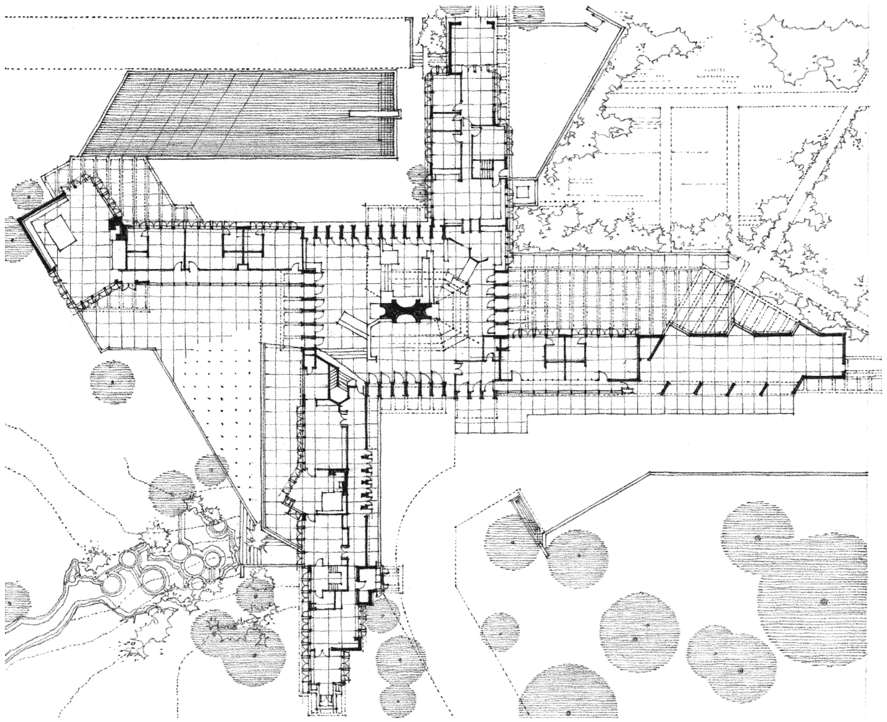


The radiating arms may also differ from one another in order to respond to individual requirements of function and context.

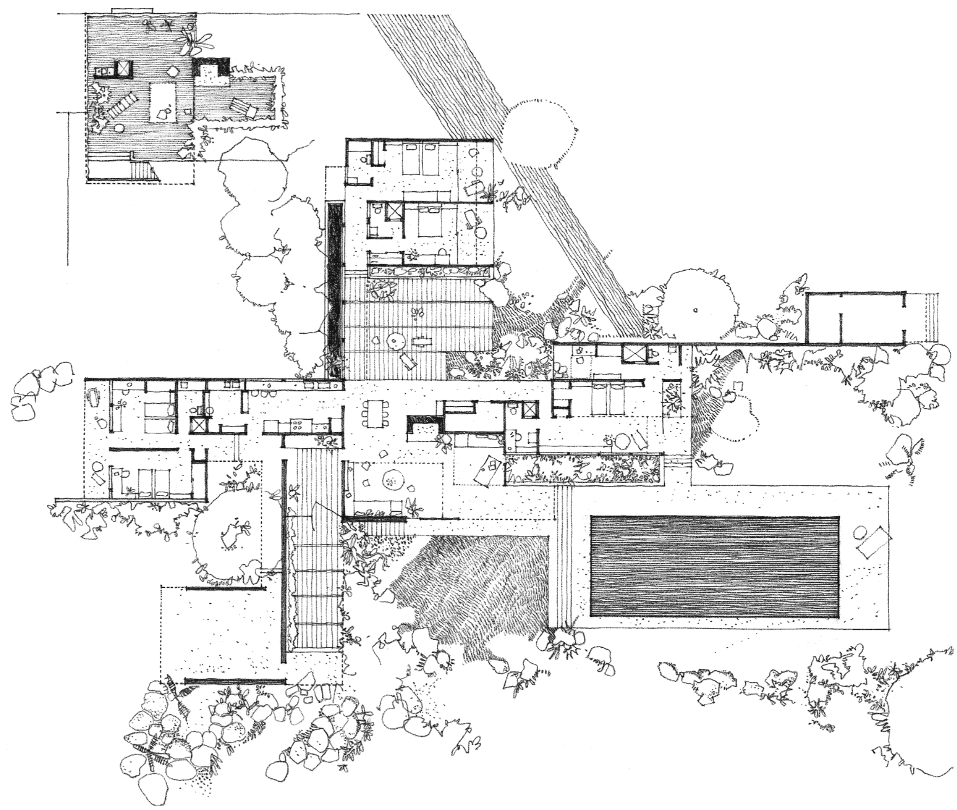
A specific variation of a radial organization is the pinwheel pattern wherein the linear arms of the organization extend from the sides of a square or rectangular central space. This arrangement results in a dynamic pattern that visually suggests a rotational movement about the central space.



Moabit Prison, Berlin, 1869–1879,
August Busse and Heinrich Herrmann



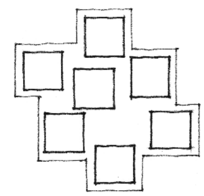
Herbert F. Johnson House (Wingspread), Wind Point, Wisconsin, 1937, Frank Lloyd Wright

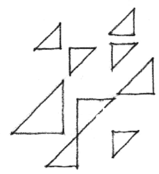


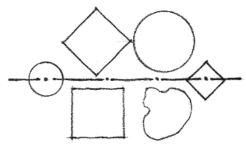
Kaufmann Desert House, Palm Springs, California, 1946, Richard Neutra

Clustered Organizations

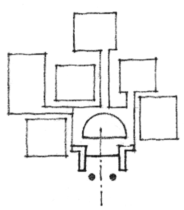
A clustered organization relies on physical proximity to relate its spaces to one another. It often consists of repetitive, cellular spaces that have similar functions and share a common visual trait such as shape or orientation. A clustered organization can also accept within its composition spaces that are dissimilar in size, form, and function, but related to one another by proximity or a visual ordering device such as symmetry or an axis. Because its pattern does not originate from a rigid geometrical concept, the form of a clustered organization is flexible and can accept growth and change readily without affecting its character.

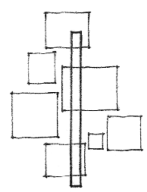

Repetitive spaces

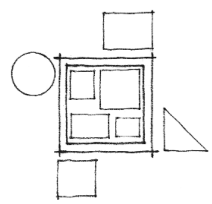

Sharing a common shape


Organized by an axis

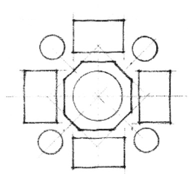
Clustered spaces can be organized about a point of entry into a building or along the path of movement through it. The spaces can also be clustered about a large defined field or volume of space. This pattern is similar to that of a centralized organization, but it lacks the latter's compactness and geometrical regularity. The spaces of a clustered organization can also be contained within a defined field or volume of space.

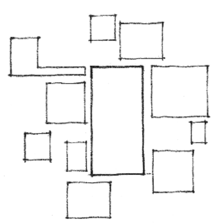

Clustered about an entry

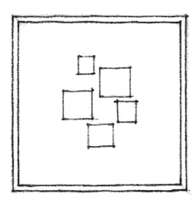

Grouped along a path


A loop path

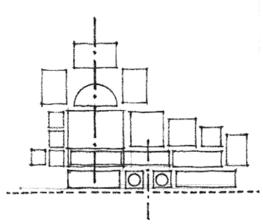
Since there is no inherent place of importance within the pattern of a clustered organization, the significance of a space must be articulated by its size, form, or orientation within the pattern.

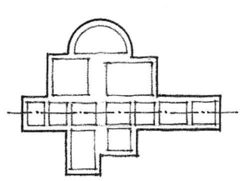

Centralized pattern

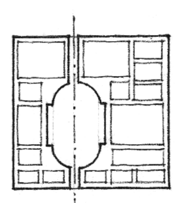

Clustered pattern

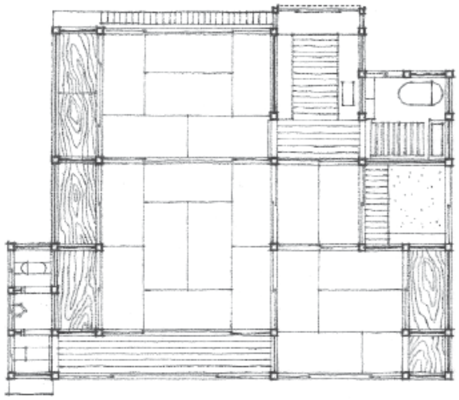

Contained within a space

Symmetry or an axial condition can be used to strengthen and unify portions of a clustered organization and help articulate the importance of a space or group of spaces within the organization.

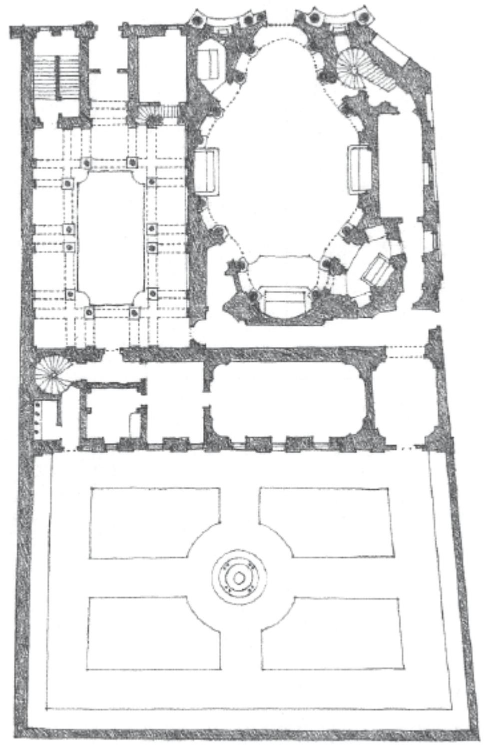

Axial conditions


Axial condition

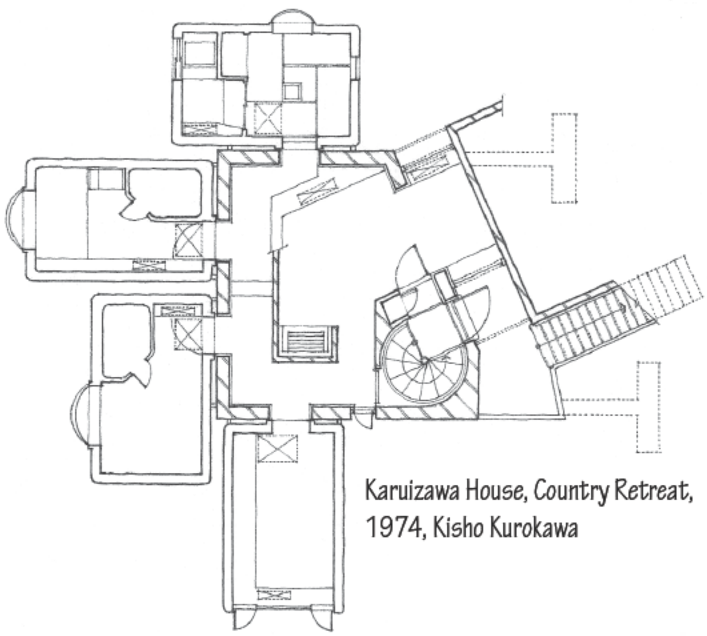

Symmetrical condition



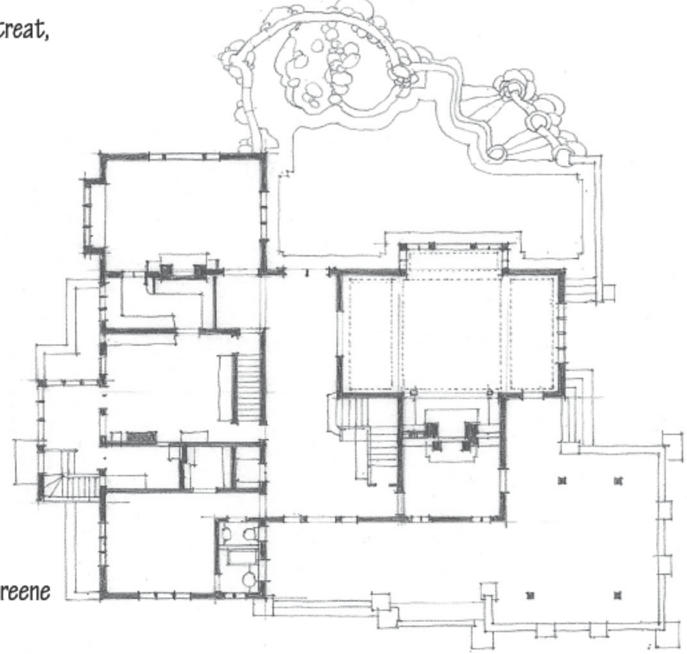
Traditional Japanese House



S. Carlo alle Quattro Fontane, Rome, 1633–1641, Francesco Borromini



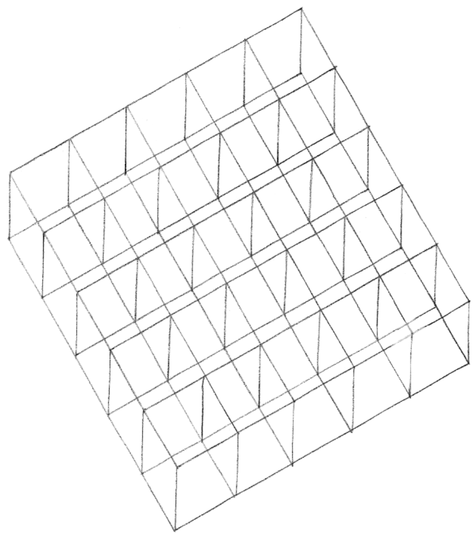
Karuizawa House, Country Retreat, 1974, Kisho Kurokawa

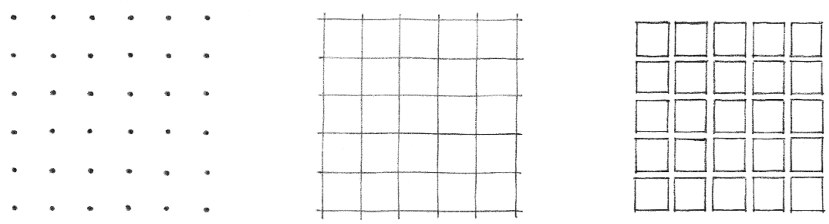


Gamble House, Pasadena, California, 1908, Greene & Greene

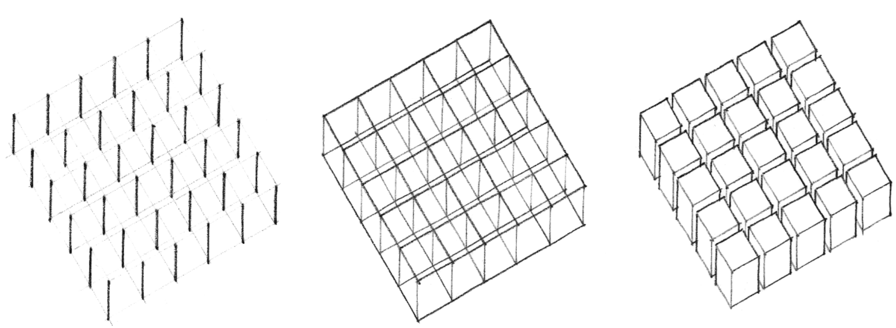
Grid Organizations

A grid organization consists of forms and spaces whose positions in space and relationships with one another are regulated by a three-dimensional grid pattern or field.

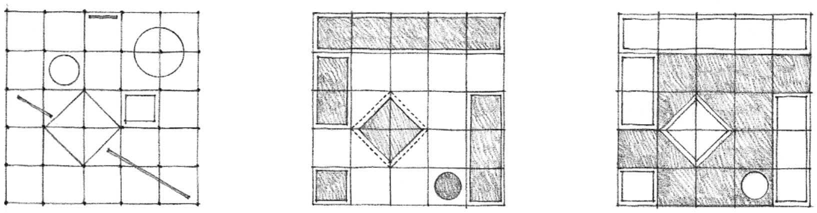




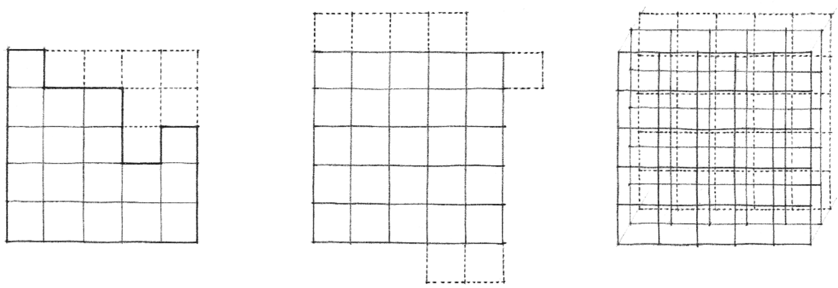
A grid is created by two, usually perpendicular, sets of parallel lines, which establish a regular pattern of points at their intersections. Projected into the third dimension, the grid pattern is transformed into a set of repetitive, modular units of space.



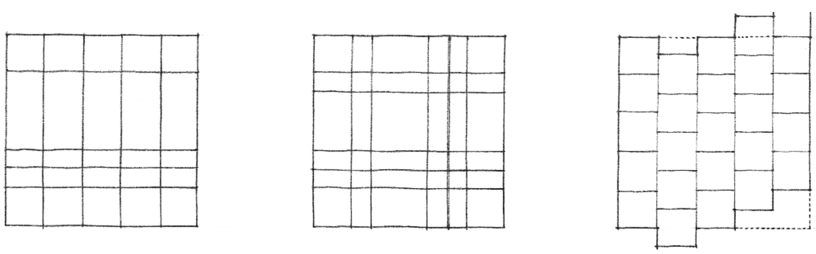
The organizing power of a grid results from the regularity and continuity of its pattern that pervades the elements it organizes. Its pattern establishes a stable set or field of reference points and lines in space with which the spaces of a grid organization, although dissimilar in size, form, or function, can share a common relationship.



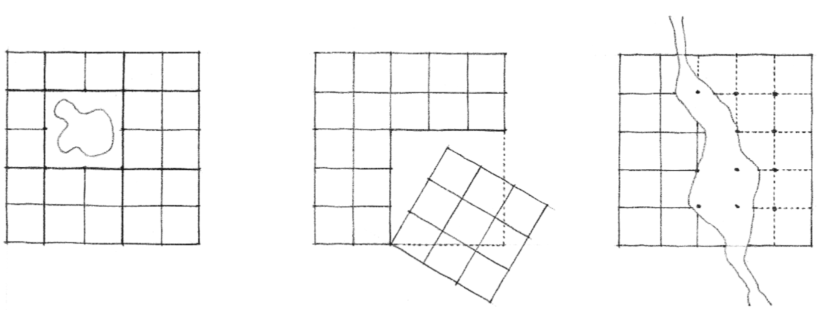
A grid is established in architecture most often by a skeletal structural system of columns and beams. Within the field of this grid, spaces can occur as isolated events or as repetitions of the grid module. Regardless of their disposition within the field, these spaces, if seen as positive forms, will create a second set of negative spaces.



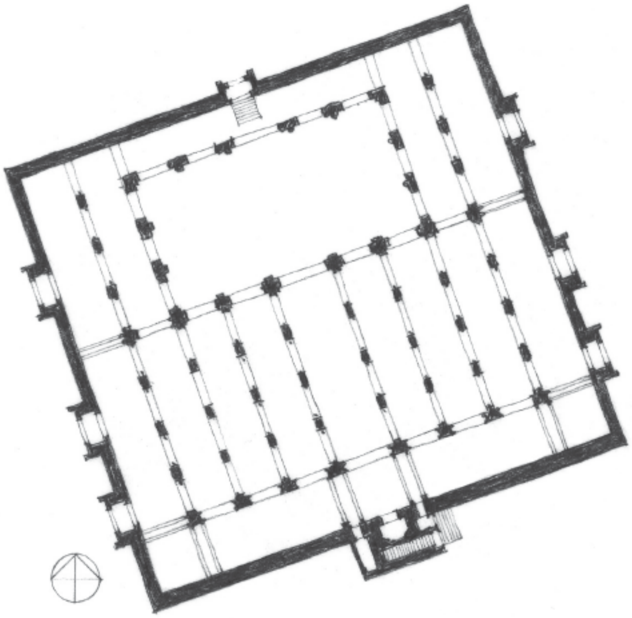
Since a three-dimensional grid consists of repetitive, modular units of space, it can be subtracted from, added to, or layered, and still maintain its identity as a grid with the ability to organize spaces. These formal manipulations can be used to adapt a grid form to its site, to define an entrance or outdoor space, or to allow for its growth and expansion.



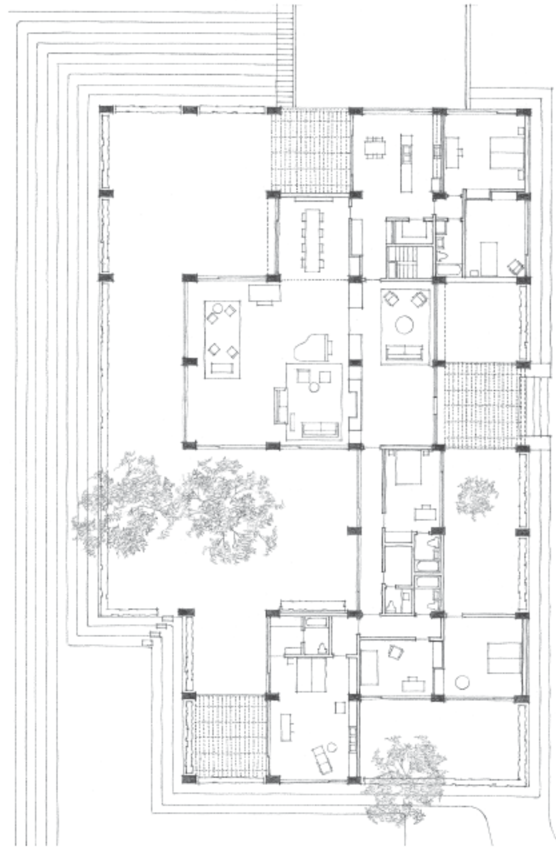
To accommodate the specific dimensional requirements of its spaces or to articulate zones of space for circulation or service, a grid can be made irregular in one or two directions. This dimensional transformation would create a hierarchical set of modules differentiated by size, proportion, and location.



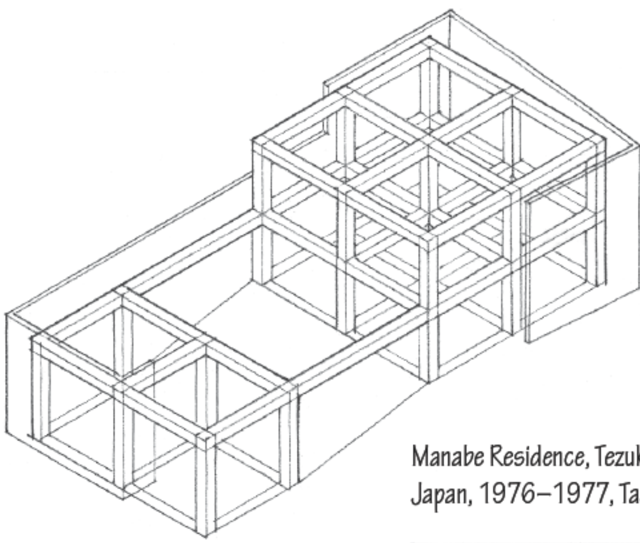
A grid can also undergo other transformations. Portions of the grid can slide to alter the visual and spatial continuity across its field. A grid pattern can be interrupted to define a major space or accommodate a natural feature of its site. A portion of the grid can be dislocated and rotated about a point in the basic pattern. Across its field, a grid can transform its image from a pattern of points to lines, to planes, and finally, to volumes.



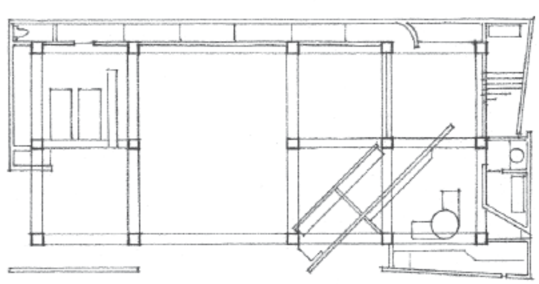
Mosque of Tinmal, Morocco, 1153–1154

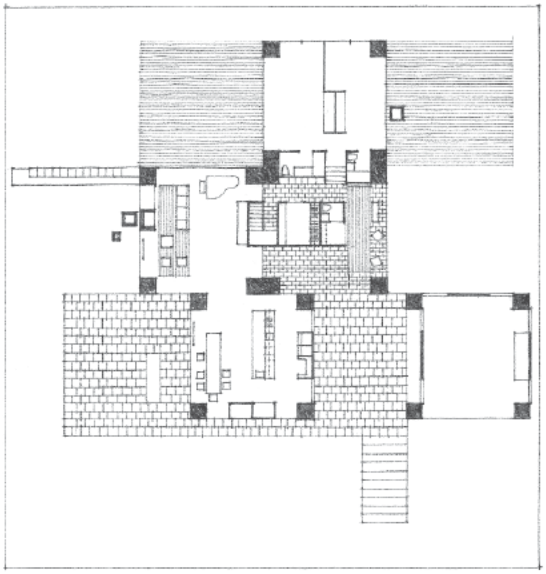


Eric Boissonas House I, New Canaan, Connecticut, 1956, Philip Johnson

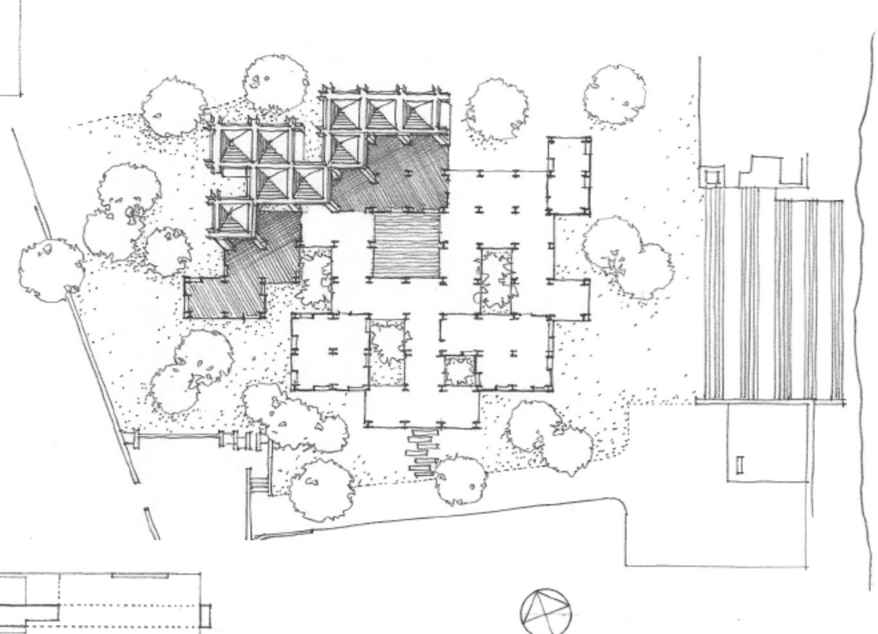


Manabe Residence, Tezukayama, Osaka, Japan, 1976–1977, Tadao Ando

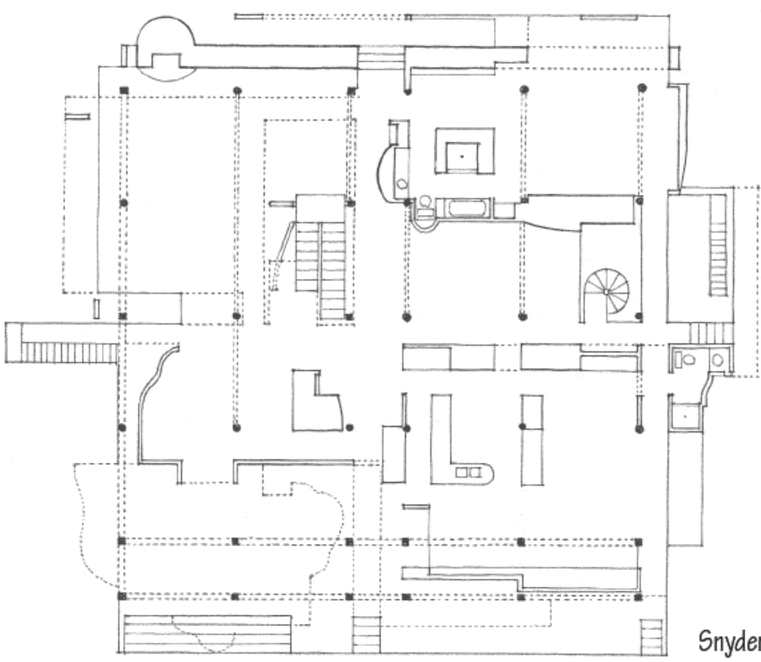




Adler House (Project), Philadelphia, Pennsylvania, 1954, Louis Kahn

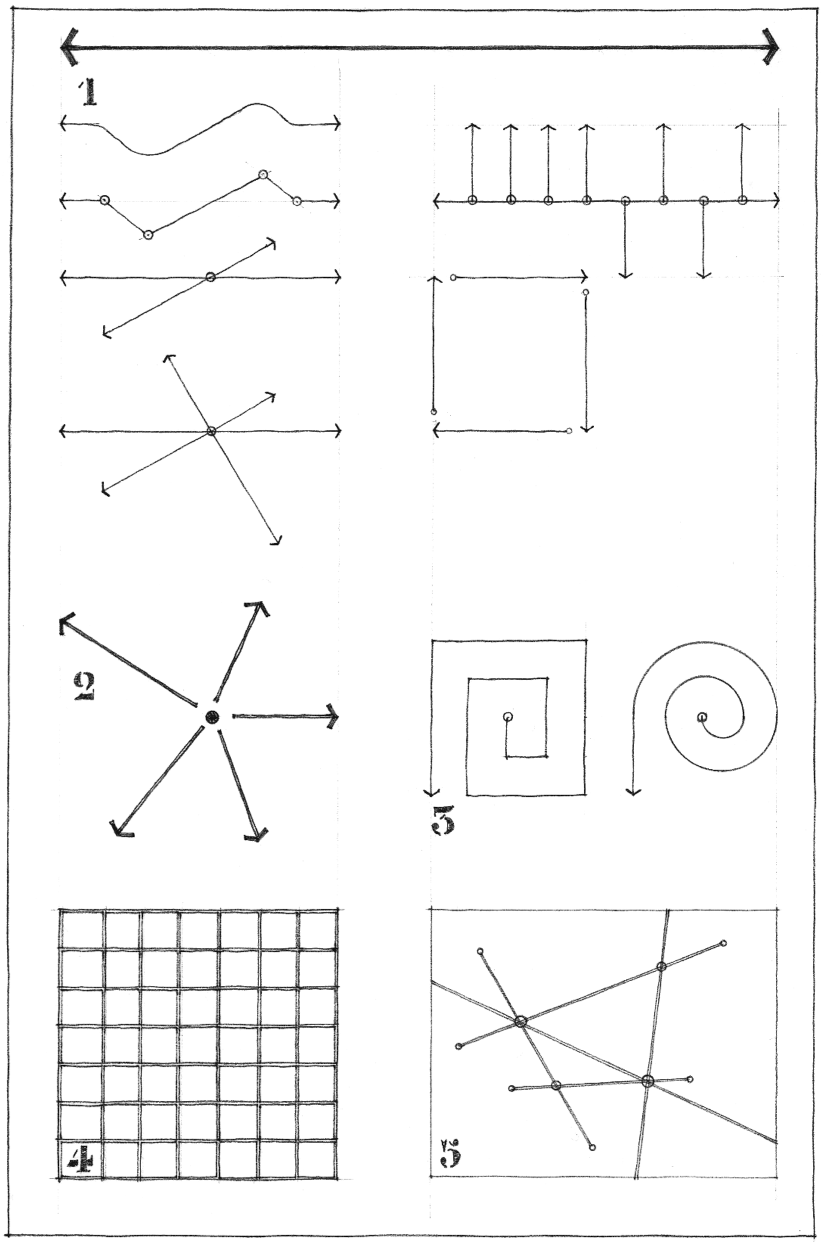


Gandhi Ashram Museum, Ahmedabad, India, 1958–1963, Charles Correa



Snyderman House, Fort Wayne, Indiana, 1972, Michael Graves

Circulation Governed by Organization



1. Linear
All paths are linear. A straight path, however, can be the primary organizing element for a series of spaces. In addition, it can be curvilinear or segmented, intersect other paths, have branches, or form a loop.

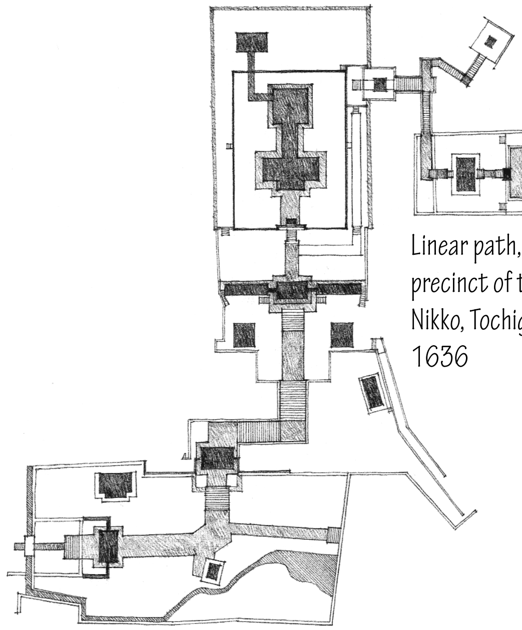
2. Radial
A radial configuration has linear paths extending from or terminating at a central, common point.

3. Spiral
A spiral configuration is a single, continuous path that originates from a central point, revolves around it, and becomes increasingly distant from it.

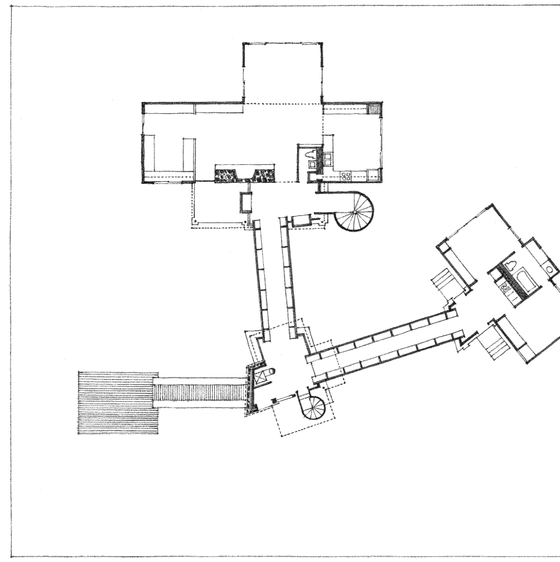
4. Grid
A grid configuration consists of two sets of parallel paths that intersect at regular intervals and create square or rectangular fields of space.

5. Network
A network configuration consists of paths that connect established points in space.

6. Composite
In reality, a building normally employs a combination of the preceding patterns. Important points in any pattern are centers of activity, entrances to rooms and halls, and places for vertical circulation provided by stairways, ramps, and elevators. These nodes punctuate the paths of movement through a building and provide opportunities for pause, rest, and reorientation. To avoid the creation of a disorienting maze, a hierarchical order among the paths and nodes of a building should be established by differentiating their scale, form, length, and placement.

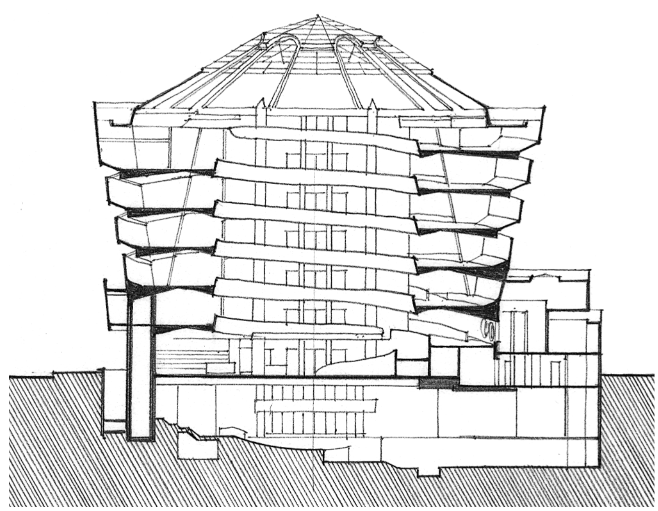


Linear path, plan of Taiyu-In precinct of the Toshogu Shrine, Nikko, Tochigi prefecture, Japan, 1636

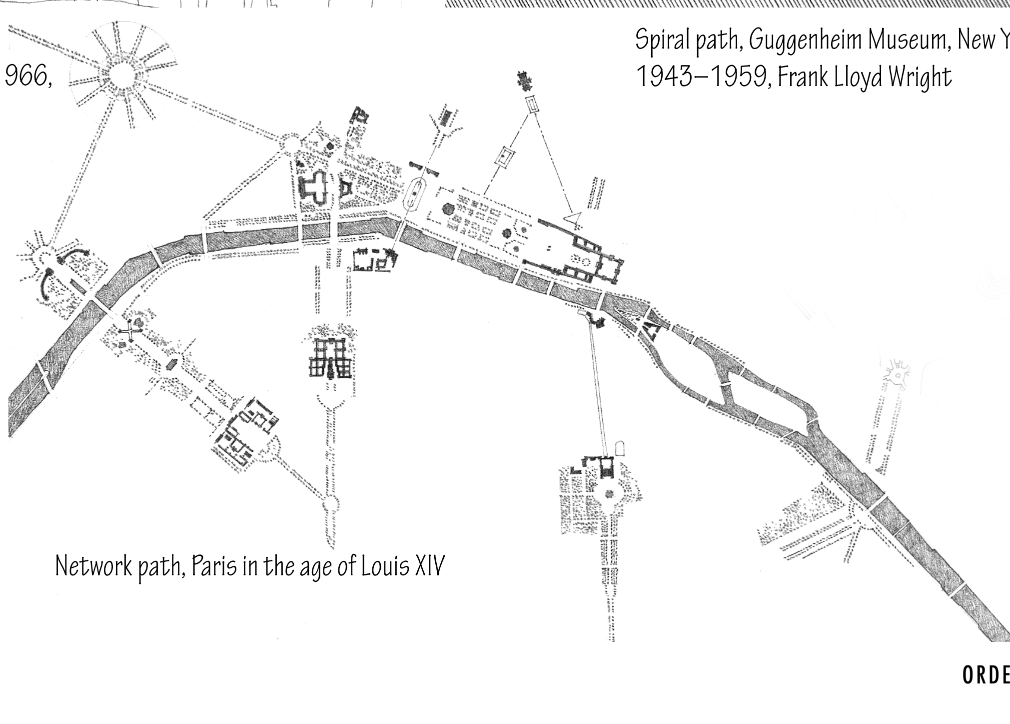


Radial path, Pope House, Connecticut, 1974–1976, John M. Johansen

Gridded path, Hospital Project, Venice, 1964–1966, Le Corbusier



Spiral path, Guggenheim Museum, New York City, 1943–1959, Frank Lloyd Wright



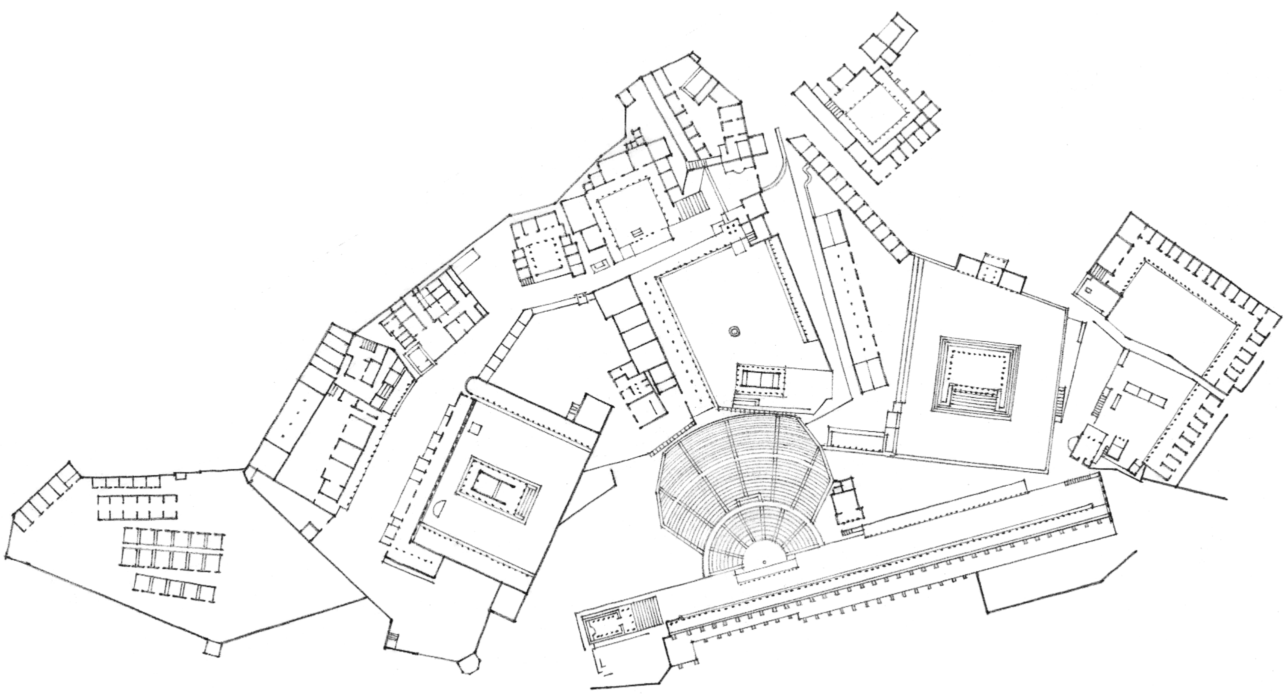
Network path, Paris in the age of Louis XIV

Ordering Principles

This section discusses additional principles that can be used to create order in an architectural composition. "Order" refers not simply to geometric regularity, but rather to a condition in which each part of a whole is properly disposed with reference to other parts and to its purpose so as to produce a harmonious arrangement.

There exists a natural diversity and complexity in the program requirements for buildings. The forms and spaces of any building should acknowledge the hierarchy inherent in the functions they accommodate, the users they serve, the purposes or meaning they convey, and the scope or context they address. It is in recognition of this natural diversity, complexity, and hierarchy in the programming, designing, and making of buildings that ordering principles are discussed.

Order without diversity can result in monotony or boredom; diversity without order can produce chaos. A sense of unity with variety is the ideal. The following ordering principles are seen as visual devices that allow the varied and diverse forms and spaces of a building to coexist perceptually and conceptually within an ordered, unified, and harmonious whole.

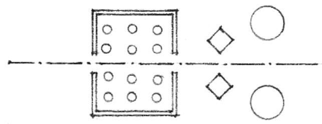


Pergamon, Plan of the Upper City, second century BCE

Axis

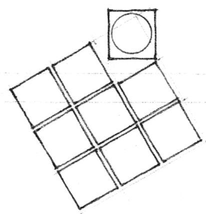
A line established by two points in space, about which forms and spaces can be arranged in a symmetrical or balanced manner.

Symmetry



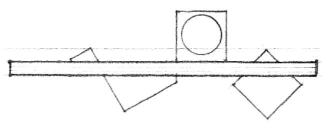
The balanced distribution and arrangement of equivalent forms and spaces on opposite sides of a dividing line or plane, or about a center or axis.

Hierarchy



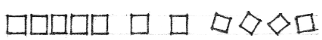
The articulation of the importance or significance of a form or space by its size, shape, or placement relative to the other forms and spaces of the organization.

Datum



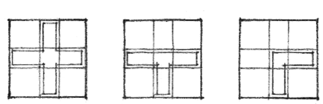
A line, plane, or volume that, by its continuity and regularity, serves to gather, measure, and organize a pattern of forms and spaces.

Rhythm

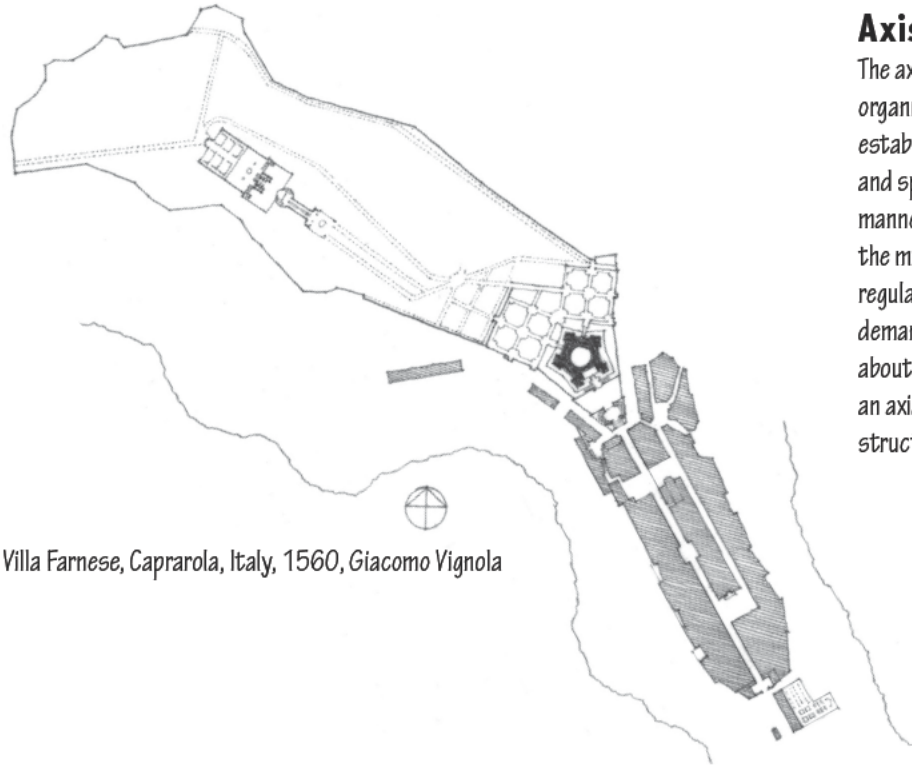


A unifying movement characterized by a patterned repetition or alternation of formal elements or motifs in the same or a modified form.

Transformation



The principle that an architectural concept, structure, or organization can be altered through a series of discrete manipulations and permutations in response to a specific context or set of conditions without a loss of identity or concept.



Villa Farnese, Caprarola, Italy, 1560, *Giacomo Vignola*

Axis

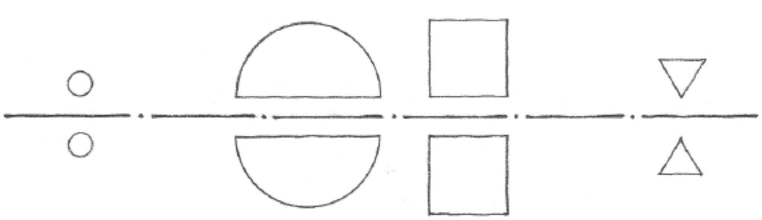
The axis is perhaps the most elementary means of organizing forms and spaces in architecture. It is a line established by two points in space, about which forms and spaces can be arranged in a regular or irregular manner. Although imaginary and not visible except to the mind's eye, an axis can be a powerful, dominating, regulating device. Although it implies symmetry, it demands balance. The specific disposition of elements about an axis will determine whether the visual force of an axial organization is subtle or overpowering, loosely structured or formal, picturesque or monotonous.

Since an axis is essentially a linear condition, it has qualities of length and direction, and induces movement and promotes views along its path

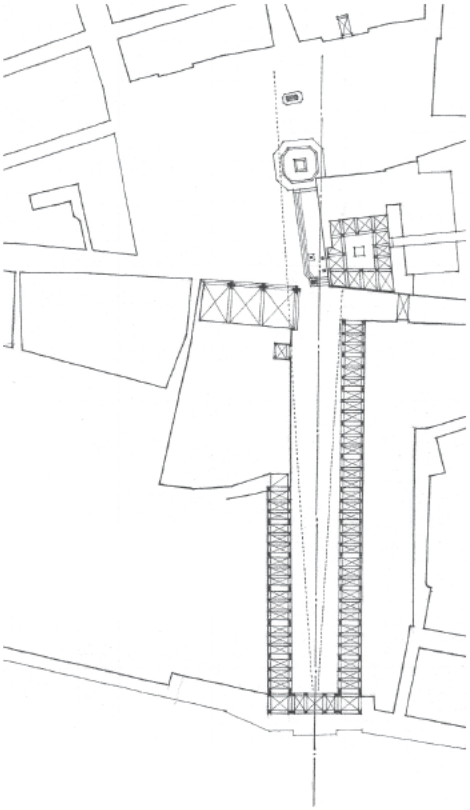
.

For its definition, an axis must be terminated at both of its ends by a significant form or space.

The notion of an axis can be reinforced by defining edges along its length. These edges can be simply lines on the ground plane, or vertical planes that define a linear space coincident with the axis.

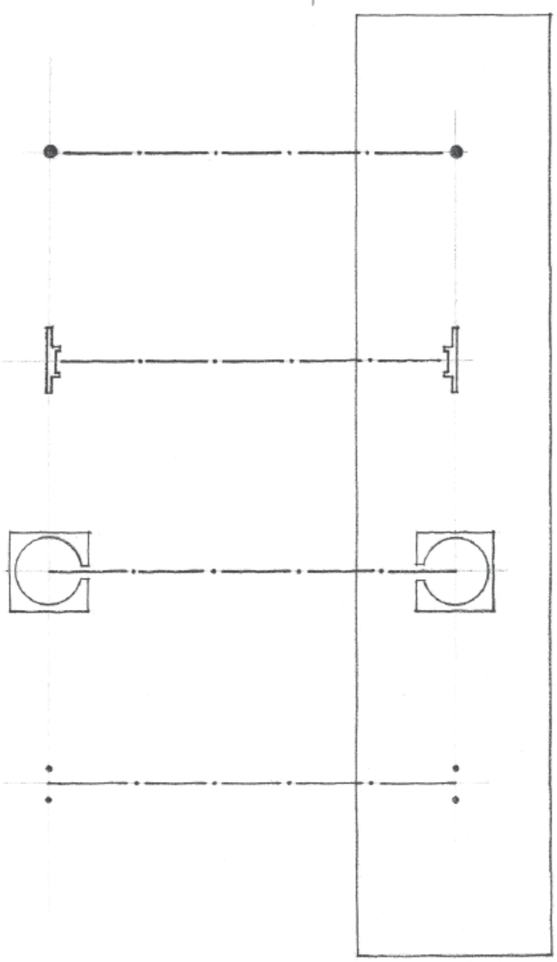


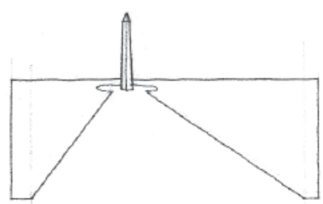
An axis can also be established simply by a symmetrical arrangement of forms and spaces.



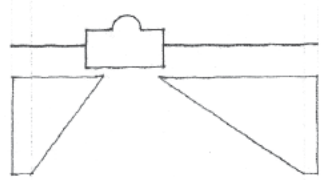
The wings of the Uffizi Palace in Florence, Italy (1560, Giorgio Vasari), frame an axial space which leads from the River Arno, through the Uffizi arch, to the Piazza della Signoria and the Palazzo Vecchio (1298–1314, Arnolfo di Cambio).

The terminating elements of an axis serve to both send and receive its visual thrust. These culminating elements can be any of the following:

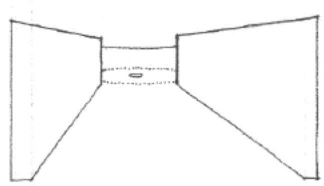




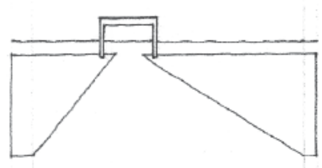
- Points in space established by vertical, linear elements or centralized building forms



- Vertical planes, such as symmetrical building facades or fronts, preceded by a forecourt or similar open space



- Well-defined spaces, generally centralized or regular in form



- Gateways that open outward toward a view or vista beyond

Symmetry

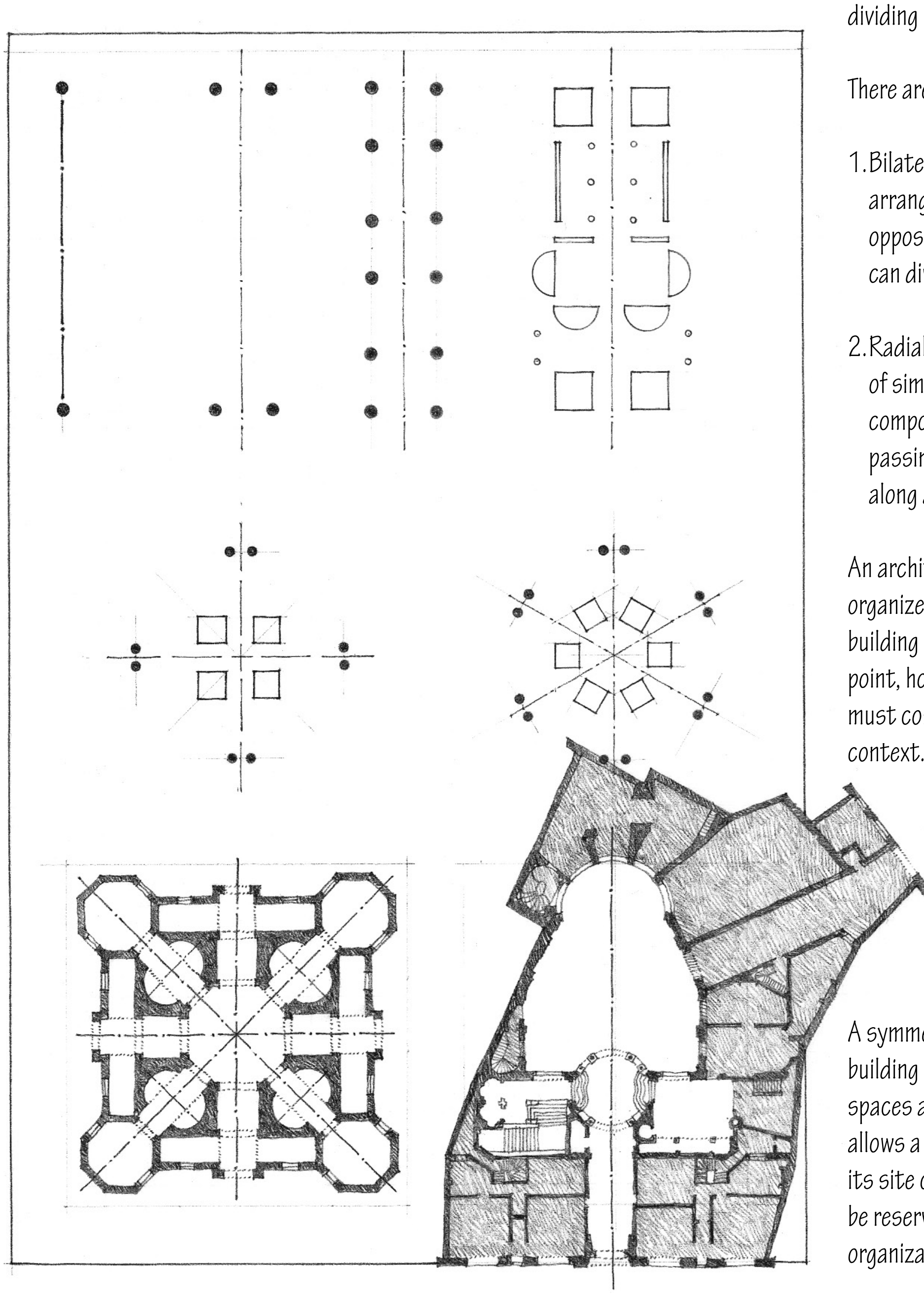
While an axial condition can exist without a symmetrical condition being simultaneously present, a symmetrical condition cannot exist without implying the existence of an axis or center about which it is structured. An axis is established by two points; a symmetrical condition requires the balanced arrangement of equivalent patterns of form and space on opposite sides of a dividing line or plane, or about a center or axis.

There are two fundamental types of symmetry:

1. Bilateral symmetry refers to the balanced arrangement of similar or equivalent elements on opposite sides of a median axis so that only one plane can divide the whole into essentially identical halves.

2. Radial symmetry refers to the balanced arrangement of similar, radiating elements such that the composition can be divided into similar halves by passing a plane at any angle around a centerpoint or along a central axis.

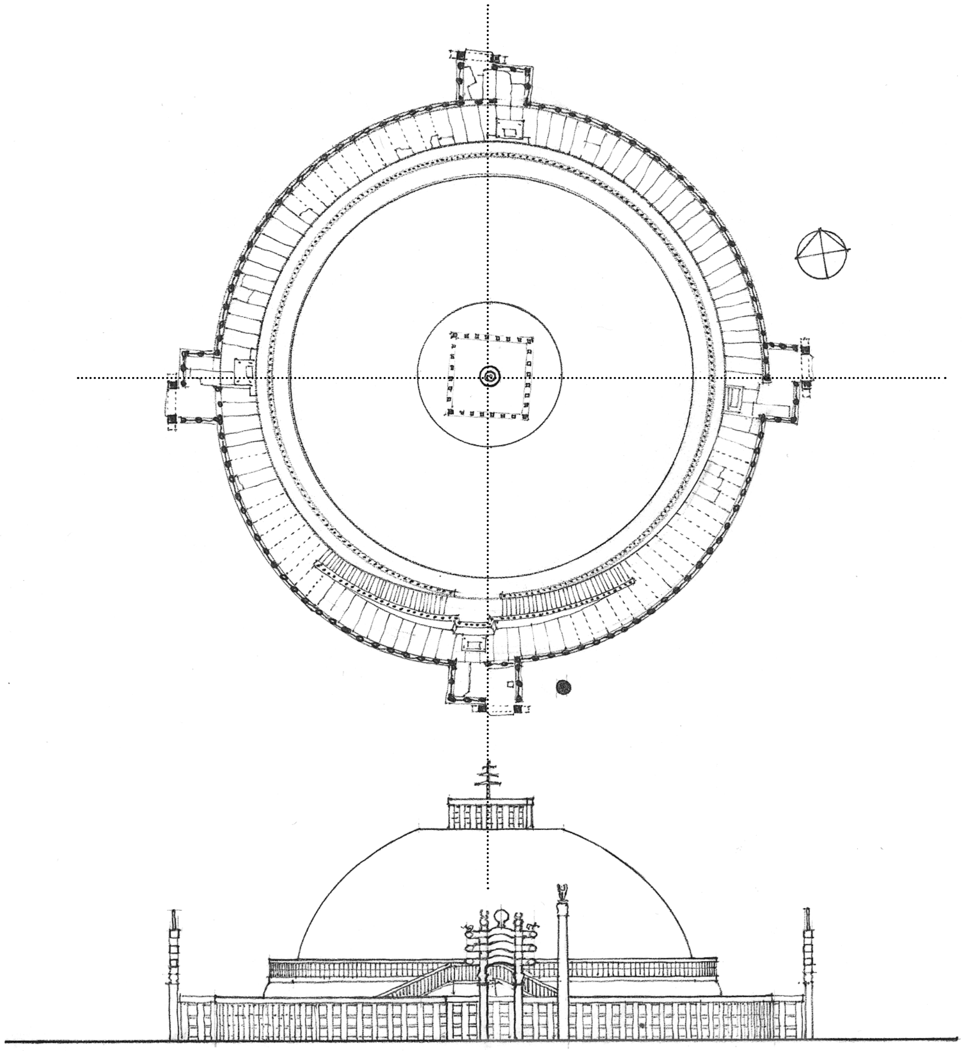
An architectural composition can use symmetry to organize its forms and spaces in two ways. An entire building organization can be made symmetrical. At some point, however, any totally symmetrical arrangement must confront and resolve the asymmetry of its site or context.



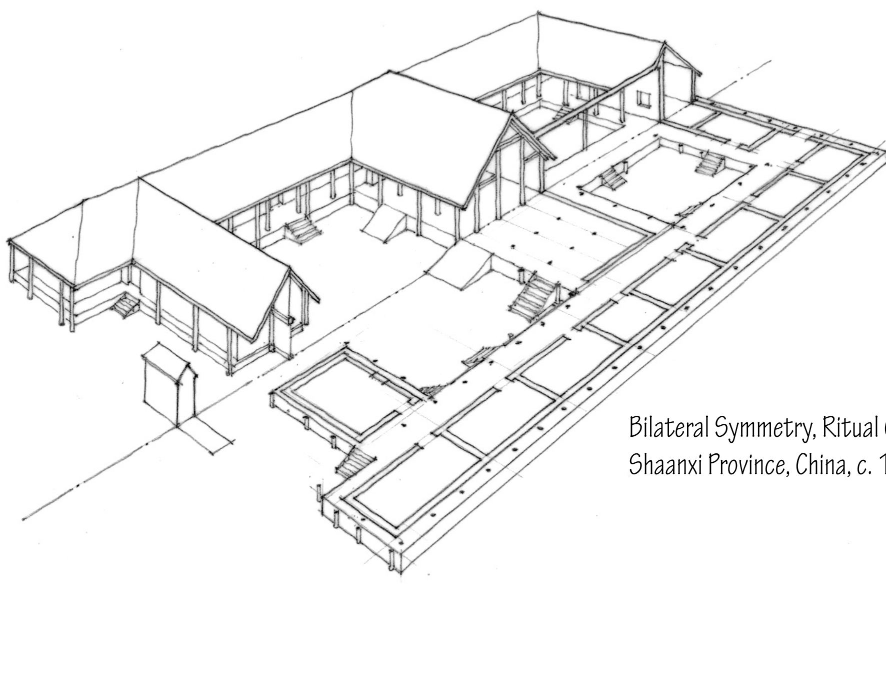
A symmetrical condition can occur in only a portion of the building and organize an irregular pattern of forms and spaces about itself. The latter case of local symmetry allows a building to respond to exceptional conditions of its site or program. The symmetrical condition itself can be reserved for significant or important spaces within the organization.

Plan of an Ideal Church, 1460, Antonio Filarete

Hôtel de Beauvais, Paris, 1656, Antoine Le Pautre



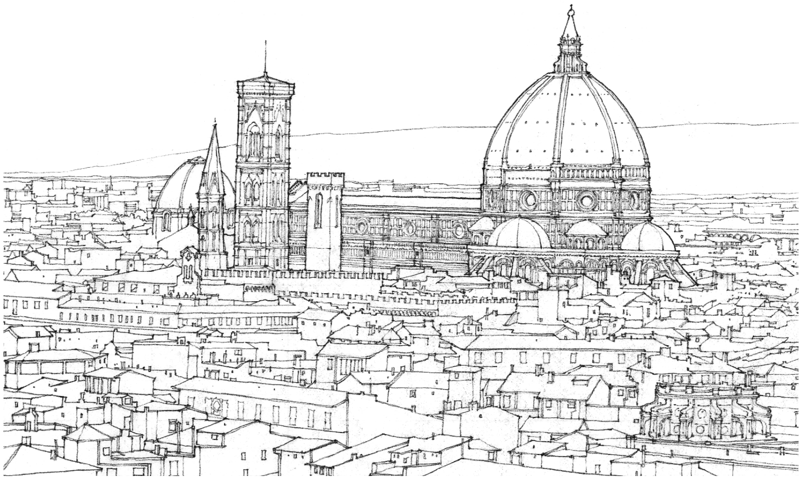
Radial symmetry, Great Stupa at Sanchi, India, c. 100 BCE



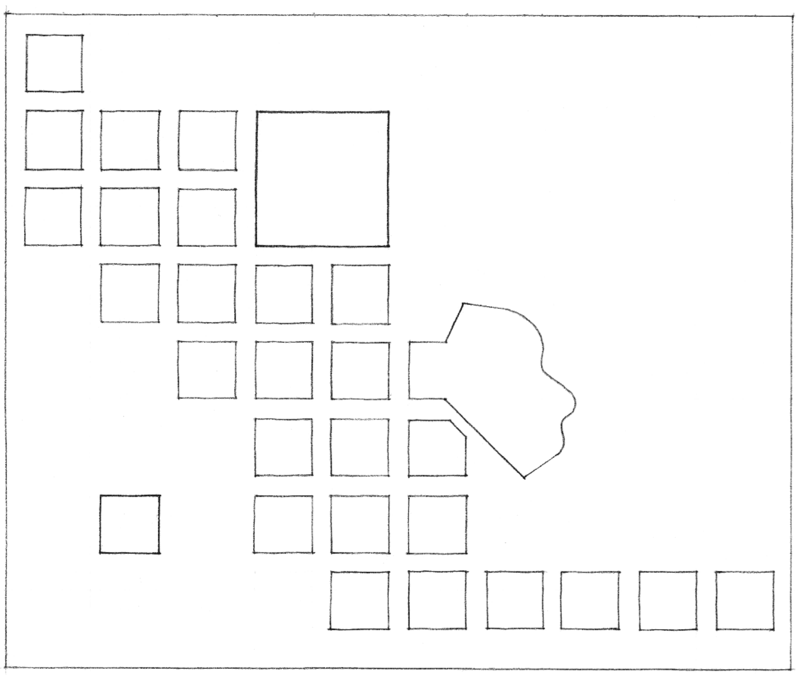
Bilateral Symmetry, Ritual Complex at Fengchu,
Shaanxi Province, China, c. 1100–1000 BCE

Hierarchy

The principle of hierarchy implies that in most if not all architectural compositions, real differences exist among their forms and spaces. These differences reflect the degree of importance of these forms and spaces, as well as the functional, formal, and symbolic roles they play in the organization. The value system by which relative importance is measured will of course depend on the specific situation, the needs and desires of the users, and the decisions of the designer. The values expressed may be individual or collective, personal or cultural. In any case, the manner in which the functional or symbolic differences among a building's elements are revealed is critical to the establishment of a visible, hierarchical order among its forms and spaces.



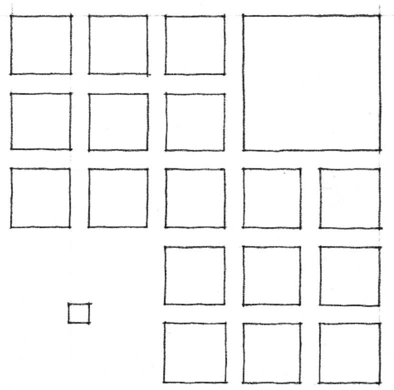
View of Florence illustrating the dominance of the cathedral over the urban landscape



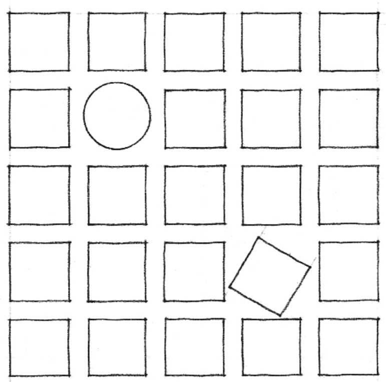
For a form or space to be articulated as being important or significant to an organization, it must be made uniquely visible. This visual emphasis can be achieved by endowing a form or shape with:

- Exceptional size
- A unique shape
- A strategic location

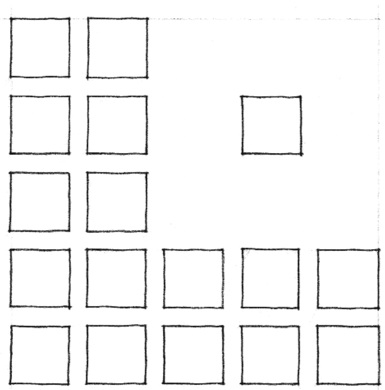
In each case, the hierarchically important form or space is given meaning and significance by being an exception to the norm, an anomaly within an otherwise regular pattern. In an architectural composition, there can be more than a single dominant element. Secondary points of emphasis, which have less attention value than the primary focal point, create visual accents. These distinctive but subordinate elements can both accommodate variety and create visual interest, rhythm, and tension in a composition. If carried too far, however, this interest may be replaced by confusion. When everything is emphasized, nothing is emphasized.



Hierarchy by Size
A form or space may dominate an architectural composition by being significantly different in size from all the other elements in the composition. Normally, this dominance is made visible by the sheer size of an element. In some cases, an element can dominate by being significantly smaller than the other elements in the organization, but placed in a well-defined setting.



Hierarchy by Shape
A form or space can be made visually dominant and, thus, important by clearly differentiating its shape from that of the other elements in the composition. A discernible contrast in shape is critical, whether the differentiation is based on a change in geometry or regularity. Of course, it is also important that the shape selected for the hierarchically significant element be compatible with its functional use.

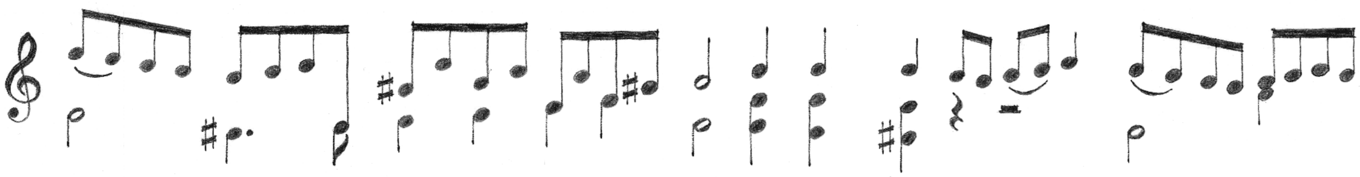


Hierarchy by Placement
A form or space may be strategically placed to call attention to itself as being the most important element in a composition. Hierarchically important locations for a form or space include:

- The termination of a linear sequence or axial organization
- The centerpiece of a symmetrical organization
- The focus of a centralized or radial organization
- Being offset above, below, or in the foreground of a composition

Datum

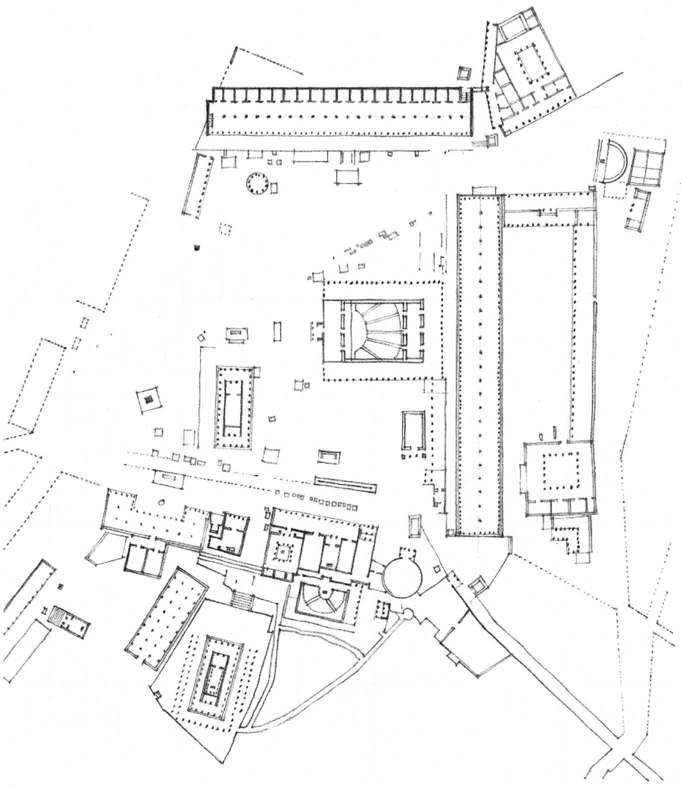
A datum refers to a line, plane, or volume of reference to which other elements in a composition can relate. It organizes a random pattern of elements through its regularity, continuity, and constant presence. For example, the lines of a musical staff serve as a datum in providing the visual basis for reading notes and the relative pitches of their tones. The regularity of their spacing and their continuity organizes, clarifies, and accentuates the differences between the series of notes in a musical composition.



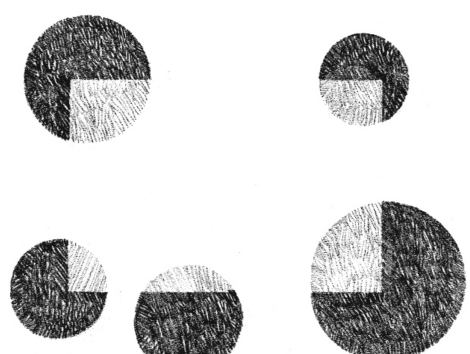
Excerpt from *Gavotte I, Sixth Cello Suite*, by Johann Sebastian Bach (1685–1750). Transcribed for classical guitar by Jerry Snyder.

A preceding section illustrated the ability of an axis to organize a series of elements along its length. In effect, the axis was serving as a datum. A datum, however, need not be a straight line. It can also be planar or volumetric in form.

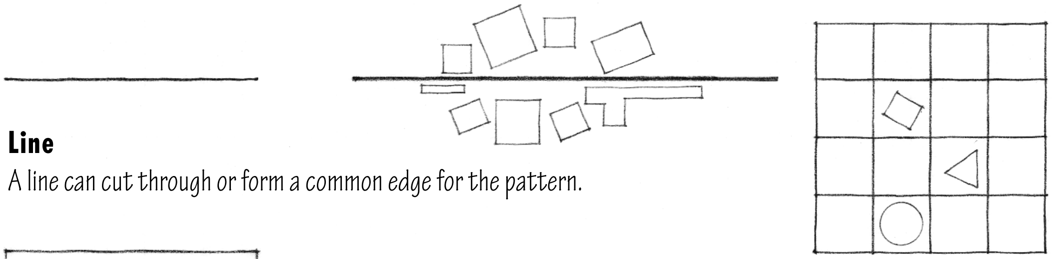
To be an effective ordering device, a linear datum must have sufficient visual continuity to cut through or bypass all of the elements being organized. If planar or volumetric in form, a datum must have sufficient size, closure, and regularity to be seen as a figure that can embrace or gather together the elements being organized within its field.



Plan of the Agora, Athens

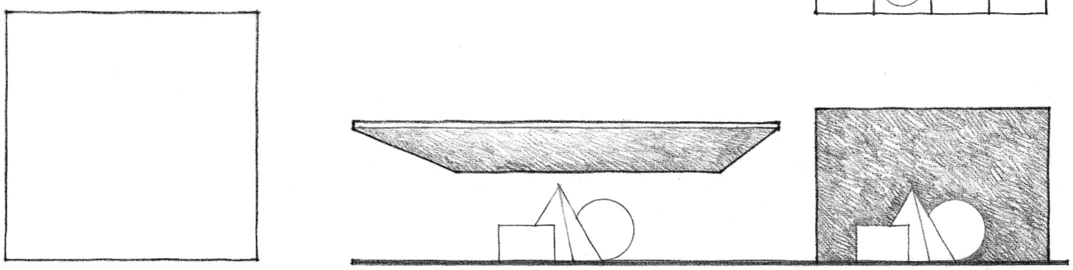


Given a random organization of dissimilar elements, a datum can organize the elements in the following ways.



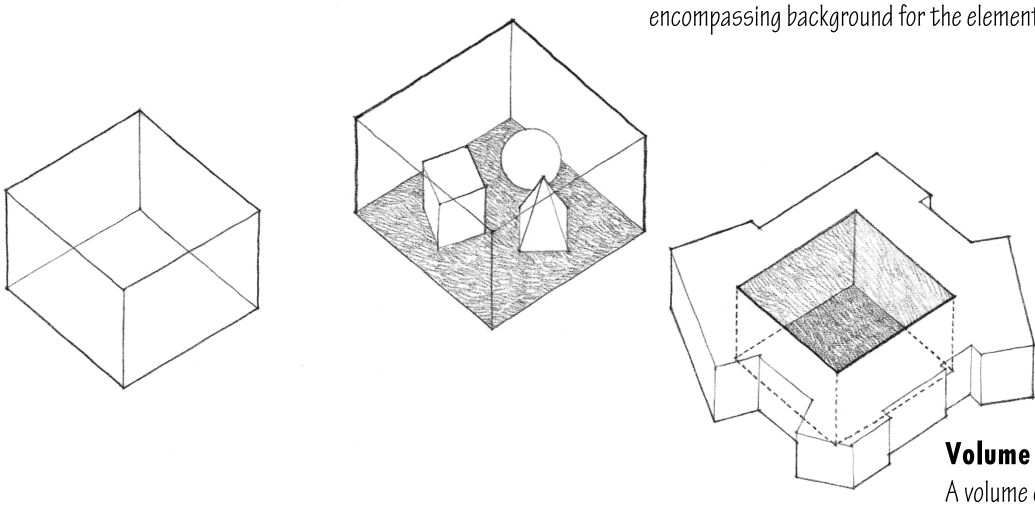
Line

A line can cut through or form a common edge for the pattern.



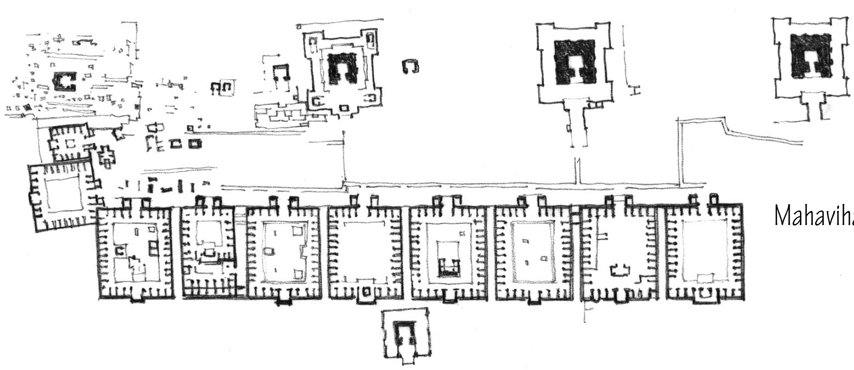
Plane

A plane can gather the pattern of elements beneath it or serve as an encompassing background for the elements and frame them in its field.



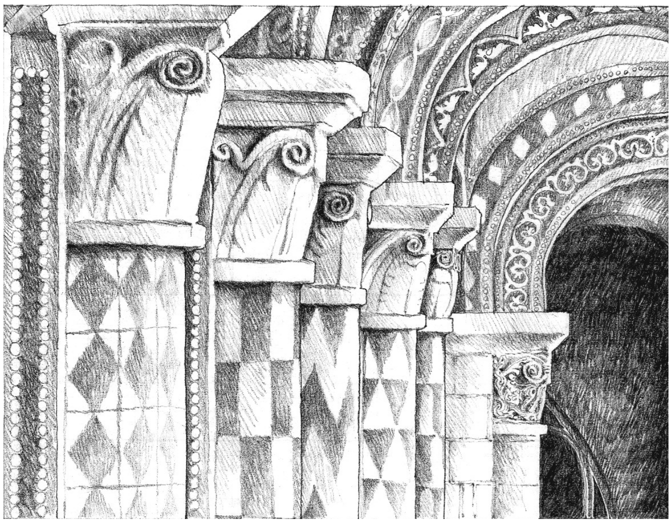
Volume

A volume can collect the pattern of elements within its boundaries or organize them along its perimeter.



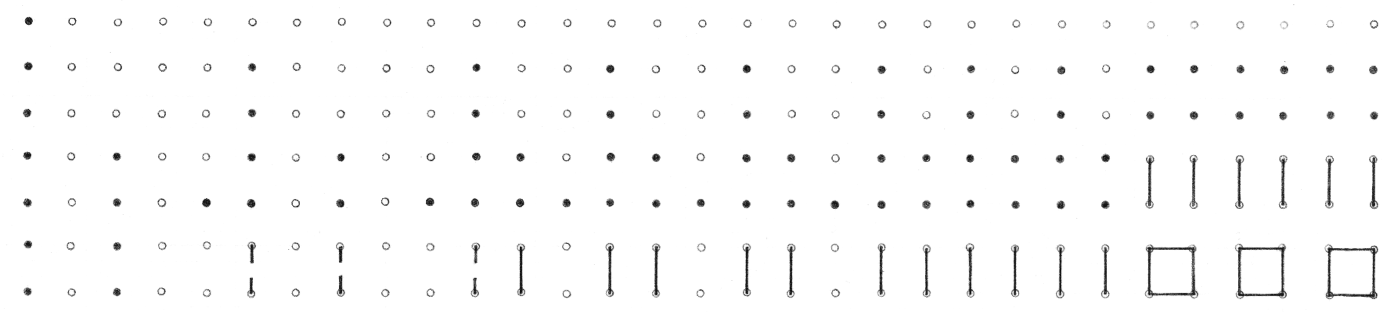
Mahavihara at Nalanda, India, sixth–seventh century CE

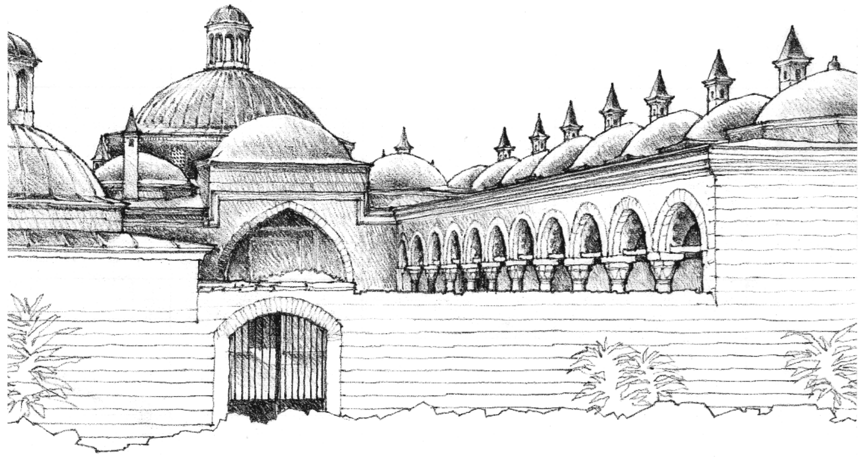
Rhythm



Rhythm refers to any movement characterized by a patterned recurrence of elements or motifs at regular or irregular intervals. The movement may be of our eyes as we follow recurring elements in a composition, or of our bodies as we advance through a sequence of spaces. In either case, rhythm incorporates the fundamental notion of repetition as a device to organize forms and spaces in architecture.

Almost all building types incorporate elements that are by their nature repetitive. Beams and columns repeat themselves to form repetitive structural bays and modules of space. Windows and doors repeatedly puncture the surfaces of a building to allow light, air, views, and people to enter the interior. Spaces often recur to accommodate similar or repetitive functional requirements in the building program. This section discusses the patterns of repetition that can be utilized to organize a series of recurring elements and the resultant visual rhythms these patterns create.



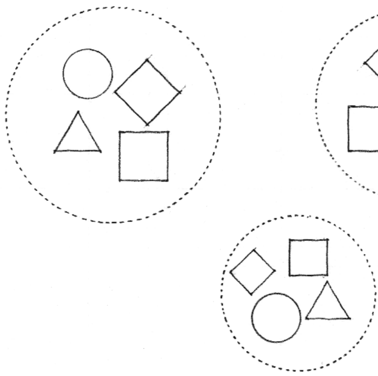


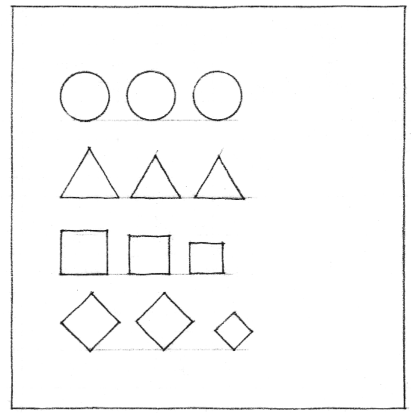
Külliye of Beyazid II, Bursa, Turkey, 1398–1403

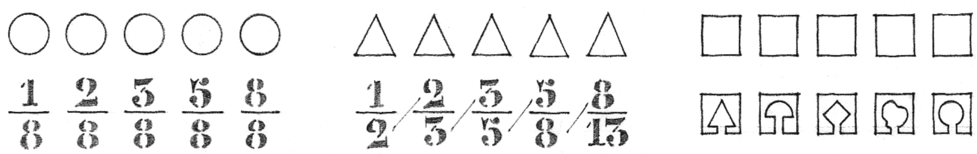
We tend to group elements in a random composition according to:

- Their closeness or proximity to one another
- The visual characteristics they share in common

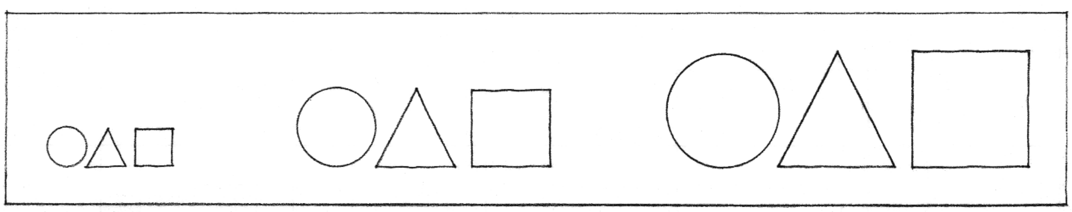
The principle of repetition utilizes both of these concepts of visual perception to order recurring elements in a composition.



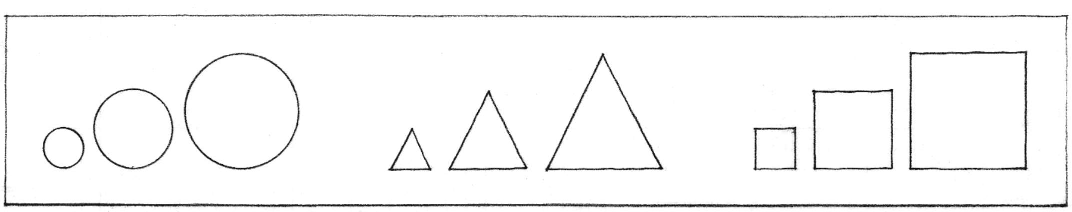




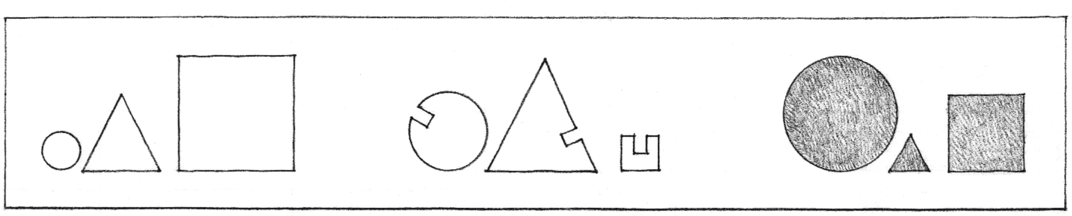
The simplest form of repetition is a linear pattern of redundant elements. Elements need not be perfectly identical, however, to be grouped in a repetitive fashion. They may merely share a common trait or a common denominator, allowing each element to be individually unique, yet belong to the same family.



Size

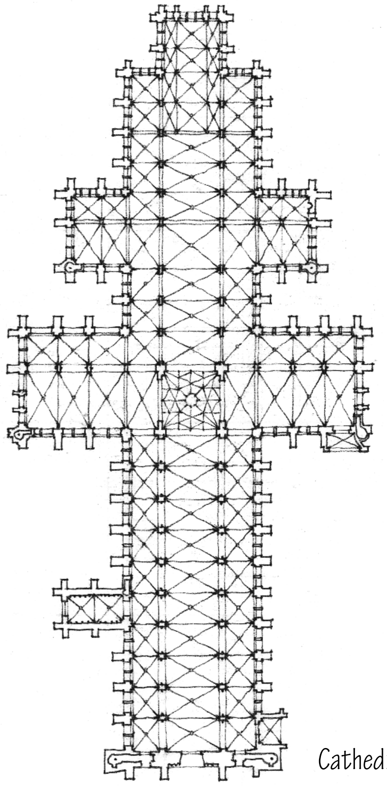


Shape

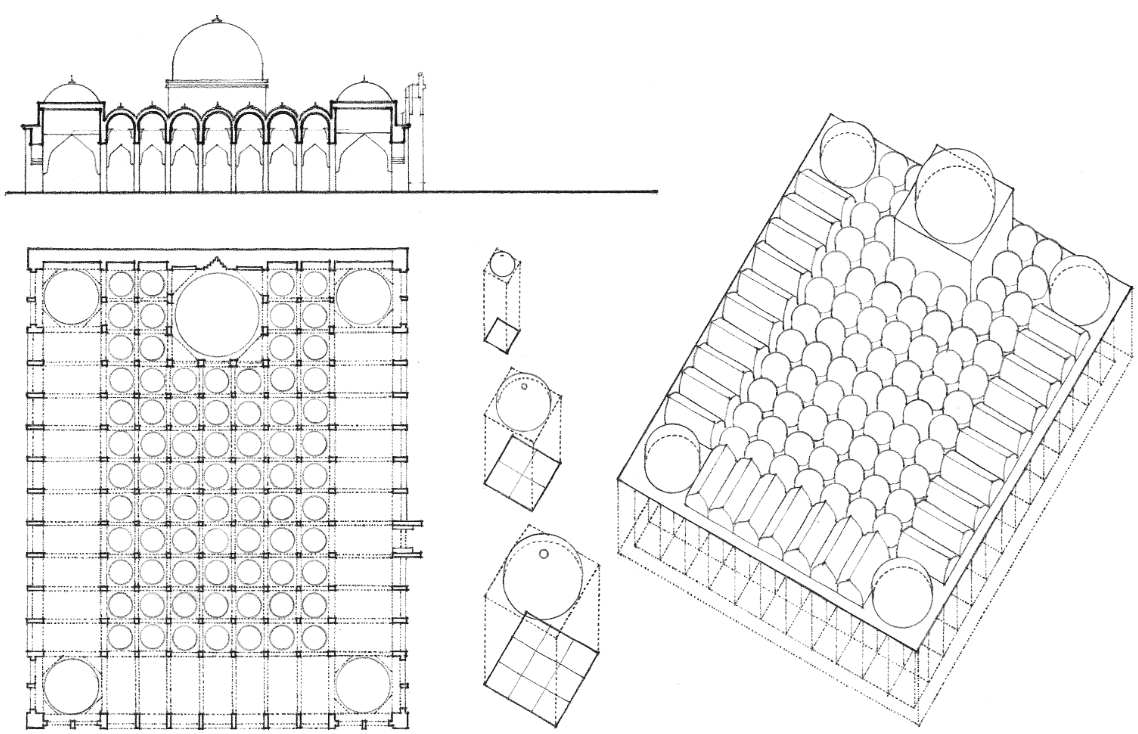


Detail characteristics

Structural patterns often incorporate the repetition of vertical supports at regular or harmonious intervals which define modular bays or divisions of space. Within such repetitive patterns, the importance of a space can be emphasized by its size and placement.

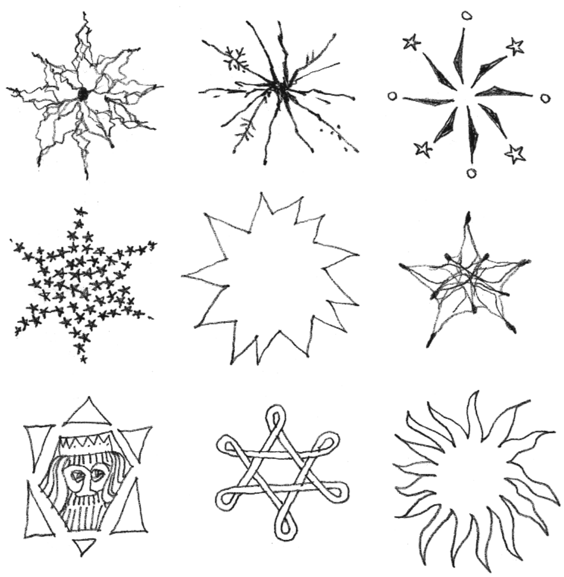


Cathedral at Salisbury, 1220–1260



Jami Masjid, Gulbarga, India, 1367

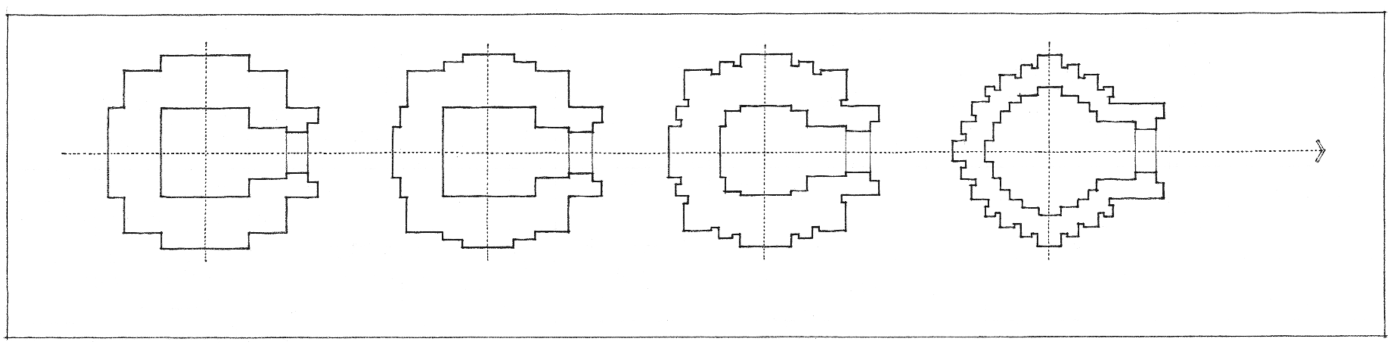
Transformation



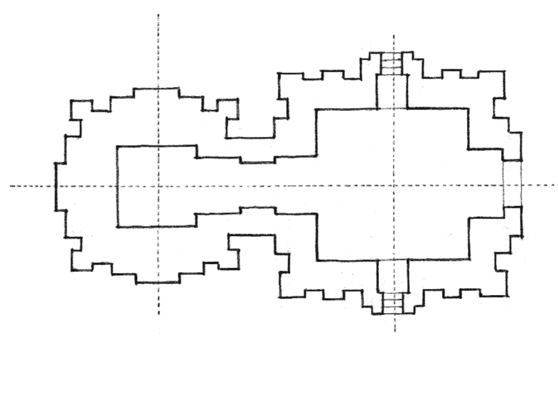
The study of architecture, as with other disciplines, should legitimately involve the study of its past, of prior experiences, endeavors, and accomplishments from which much can be learned and emulated. The principle of transformation accepts this notion; this book, and all of the examples it contains, is predicated on it.

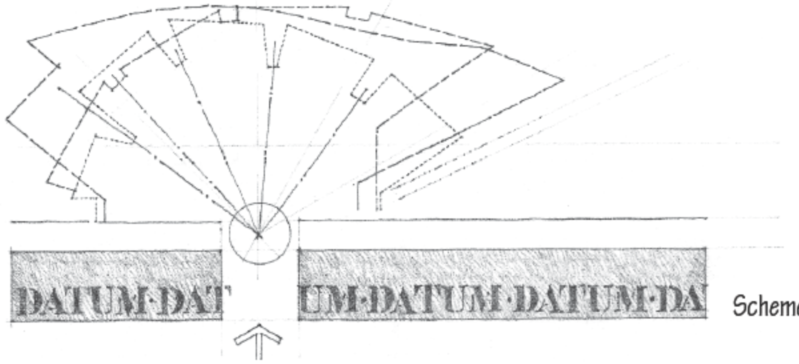
The principle of transformation allows a designer to select a prototypical architectural model whose formal structure and ordering of elements might be appropriate and reasonable, and to transform it through a series of discrete manipulations in order to respond to the specific conditions and context of the design task at hand.

Design is a generative process of analysis and synthesis, of trial and error, of trying out possibilities and seizing opportunities. In the process of exploring an idea and probing its potential, it is essential that a designer understand the fundamental nature and structure of the concept. If the ordering system of a prototypical model is perceived and understood, then the original design concept can, through a series of finite permutations, be clarified, strengthened, and built upon, rather than destroyed.

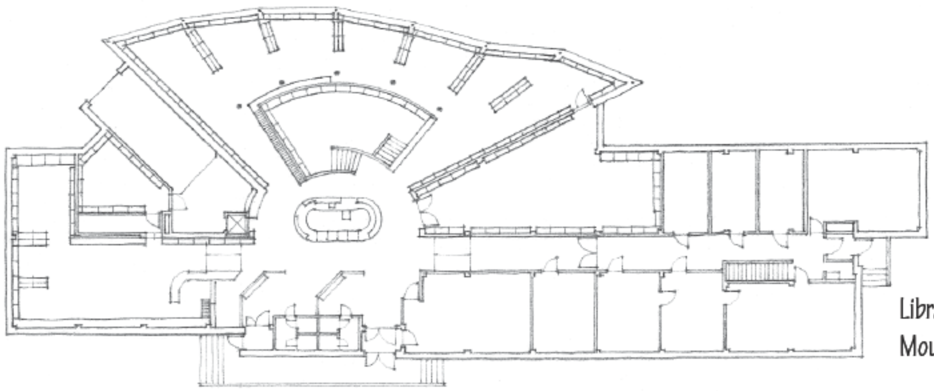


Plan development of the North Indian Cella

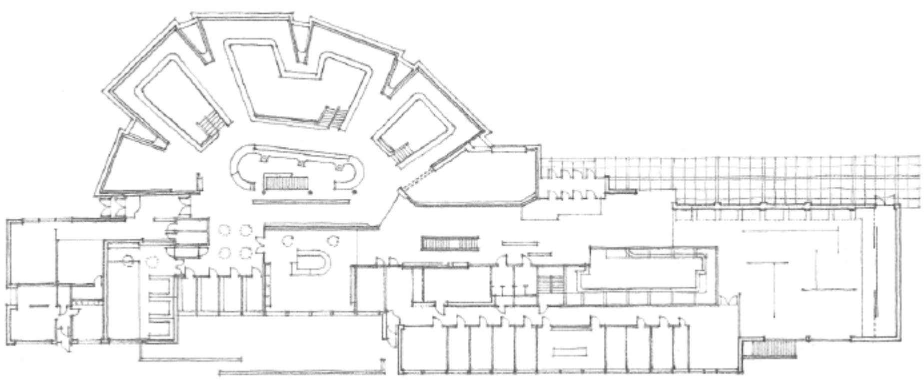




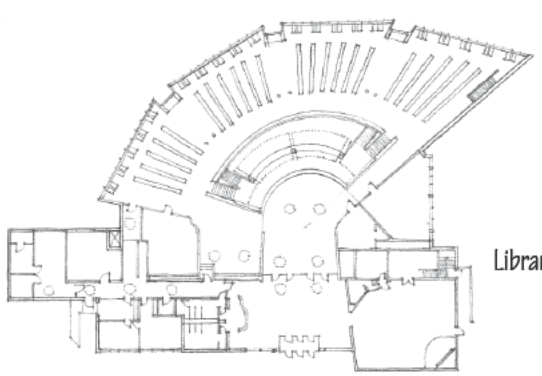
Scheme for 3 libraries by Alvar Aalto



Library of Mount Angel, Benedictine College,
Mount Angel, Oregon, 1965–1970



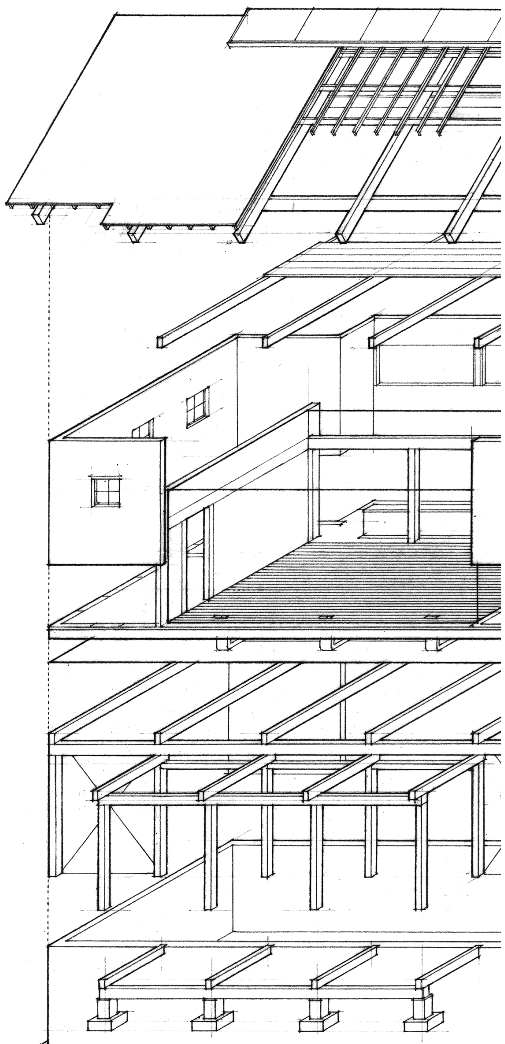
Library, Seinäjoki, Finland, 1963–1965



Library, Rovaniemi, Finland, 1963–1968

7 Elements of Architecture:

Types, Systems, and Components That Inform Design



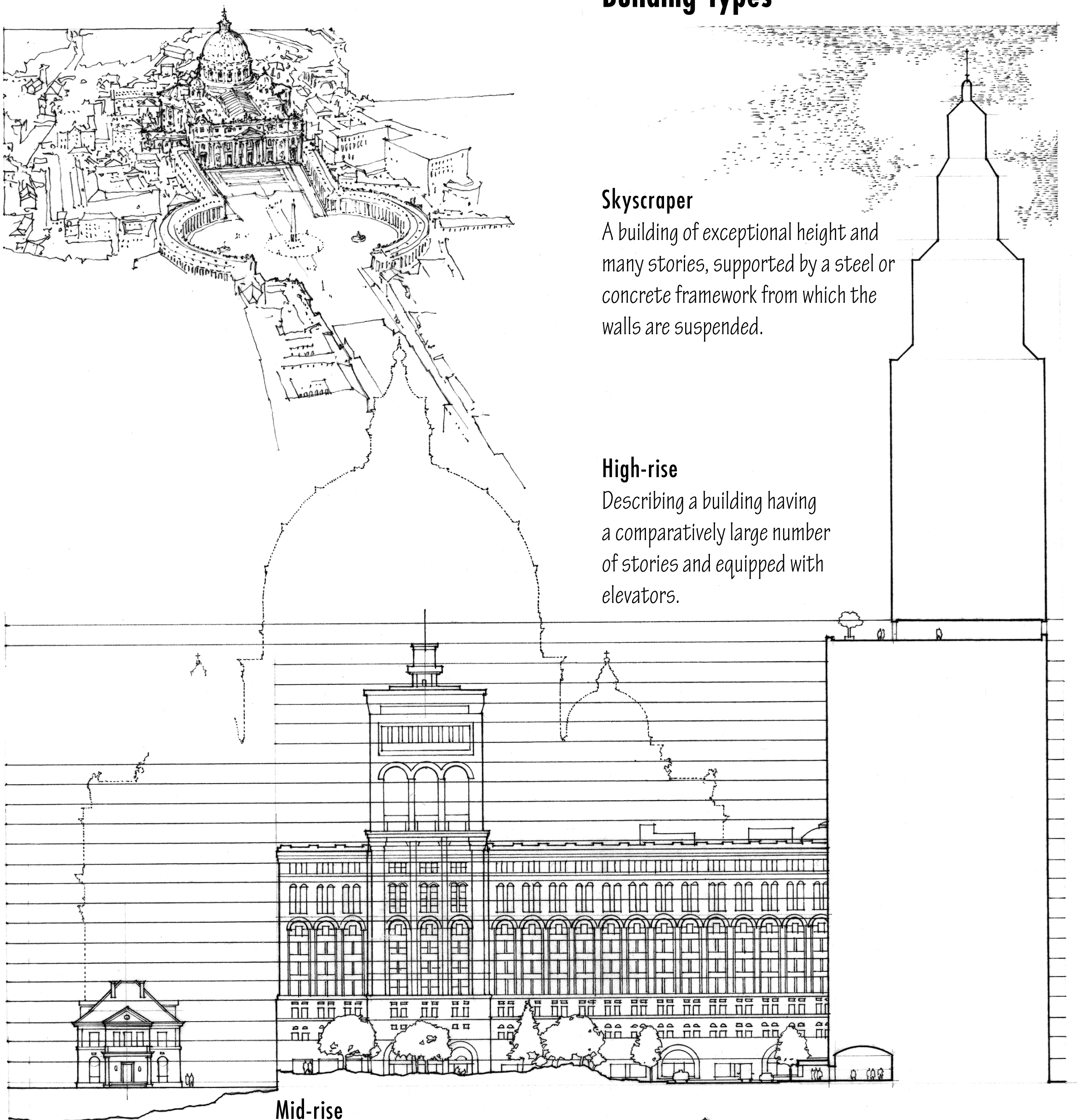
What Are the Components of Architecture?

Realizing a building requires more than the compositional sensibilities of form, space, and order. The relationships established through basic composition are realized through the position and assembly of many different architectural components. These components range in size, complexity, and function.

The smallest are the details that prescribe the way an occupant interacts with their surroundings—a handle to grasp or a sill upon which an object can be placed.

The largest of these components enable the building to behave in a predictable way that correlates with the design intent—a column grid provides structure and divides a space into bays; a roof structure protects from the elements and defines the vertical limit of space.
In this chapter, the anatomy of architecture is understood. Buildings are divided into their most basic elements. Types and options available for each of those elements are then defined. The information in this chapter is intended to provide an overview of architectural possibilities, but it is by no means an exhaustive list. Architecture, by its very nature, is a discipline that is constantly expanding its potential through invention and innovation. It is important to remember that this chapter provides an overview of only basic components and that the possibilities of architectural form are much more diverse.

Building Types

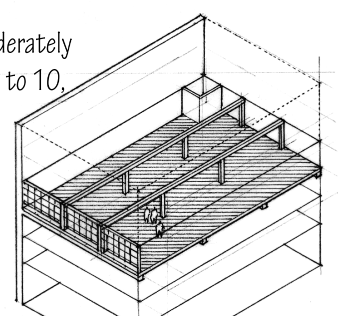


Skyscraper
A building of exceptional height and many stories, supported by a steel or concrete framework from which the walls are suspended.

High-rise
Describing a building having a comparatively large number of stories and equipped with elevators.

Low-rise
Describing a building having one, two, or three stories and usually no elevator.

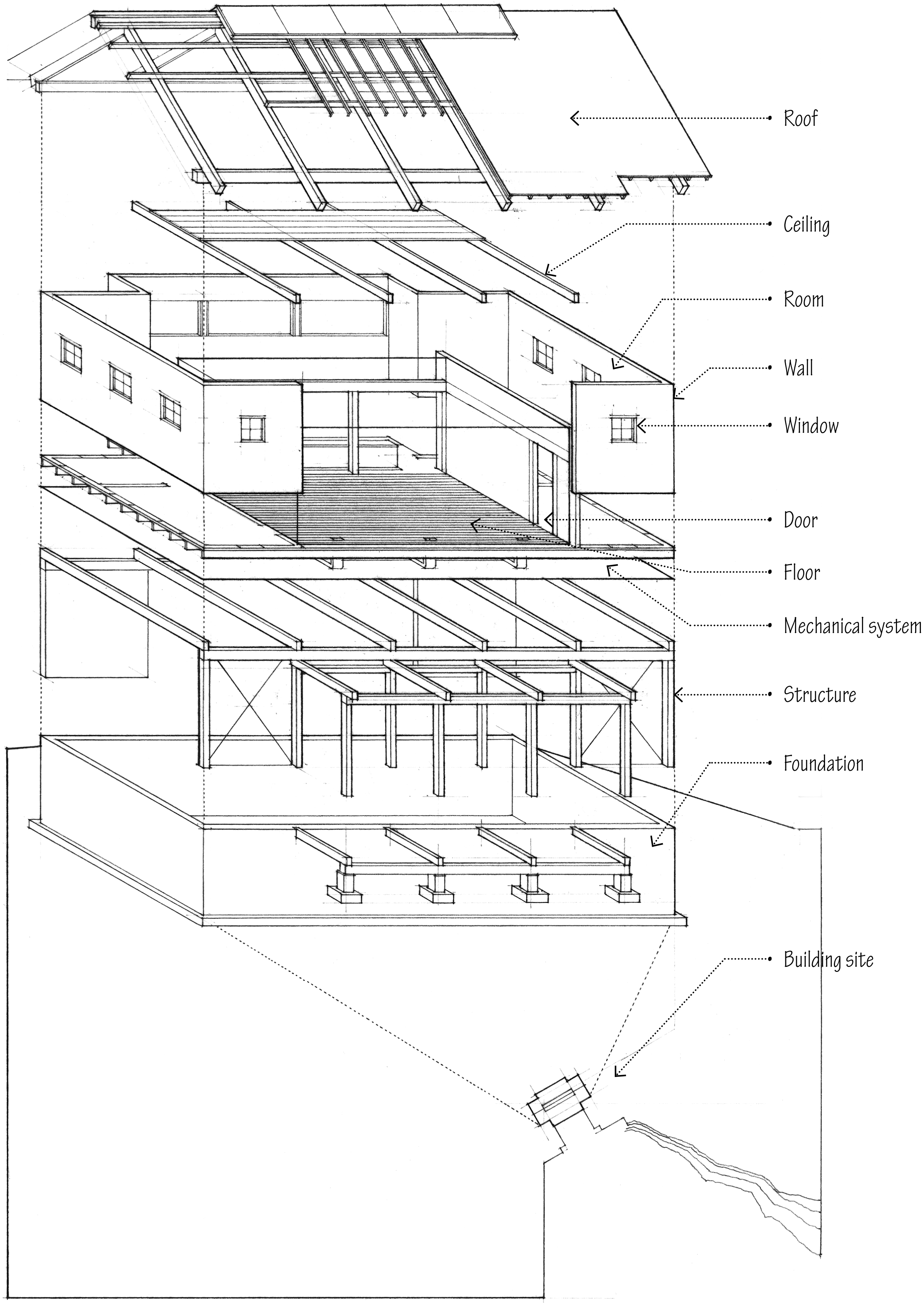
Mid-rise
Describing a building having a moderately large number of stories, usually 5 to 10, and equipped with elevators.



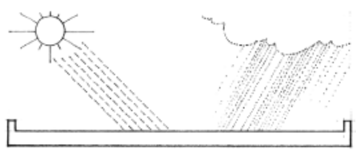
Loft
One of the upper floors of a warehouse or factory, typically unpartitioned and sometimes converted or adapted to other uses, such as living quarters, artists' studios, or exhibition galleries.

Loft building
A building having several floors with large areas of unobstructed space, originally rented out for light industrial purposes and now frequently converted to residential occupancy.

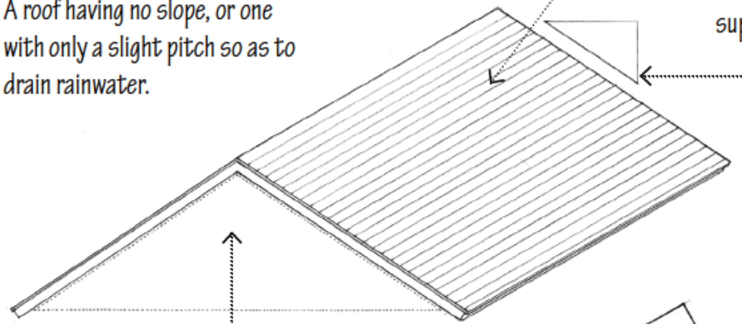
Basic Elements of a Building



Roof



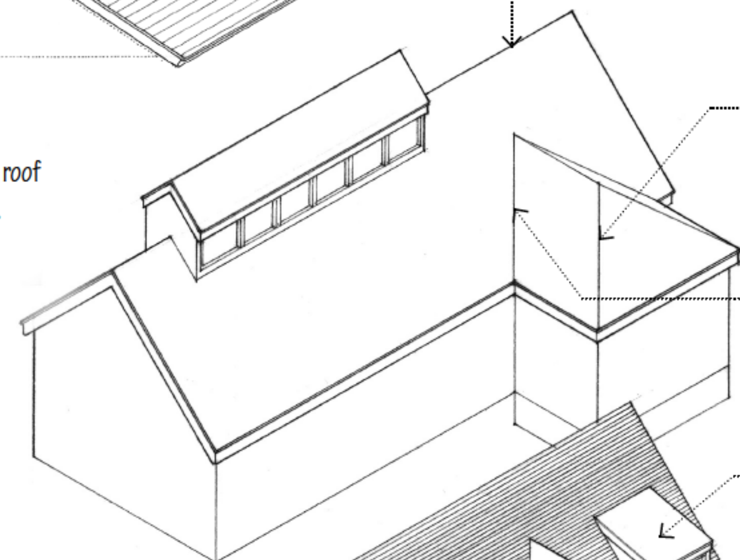
Flat roof
A roof having no slope, or one with only a slight pitch so as to drain rainwater.



Roof
The external upper covering of a building, including the frame for supporting the roofing.

Pitched roof
A roof having one or more slopes.

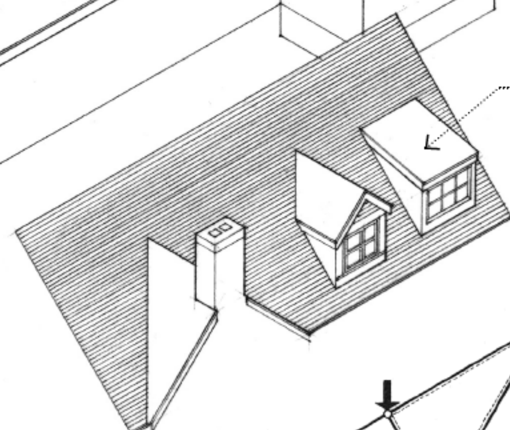
Gable
The triangular portion of wall enclosing the end of a pitched roof from cornice or eaves to ridge.



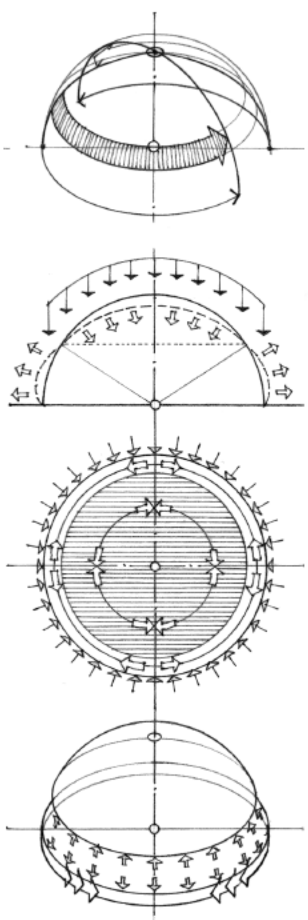
Ridge
A horizontal line of intersection at the top between two sloping planes of a roof.

Hip
The inclined projecting angle formed by the junction of two adjacent sloping sides of a roof.

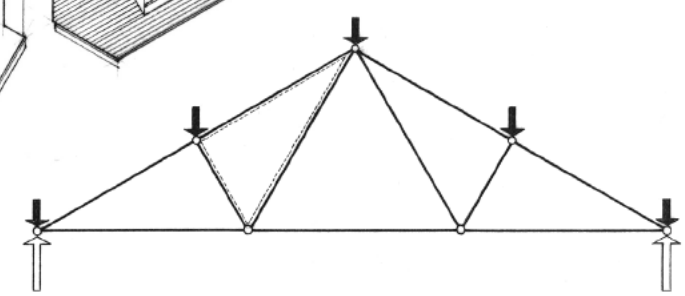
Valley
An intersection of two inclined roof surfaces toward which rainwater flows.

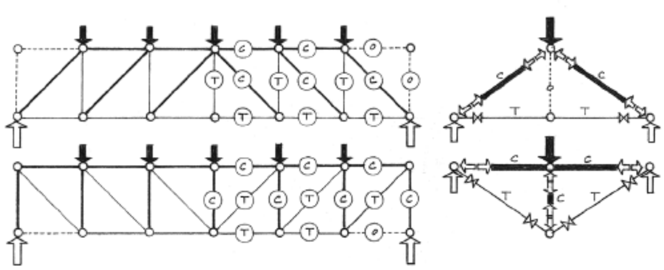


Dormer
A projecting structure built out from a sloping roof, usually housing a vertical window or ventilating louver.



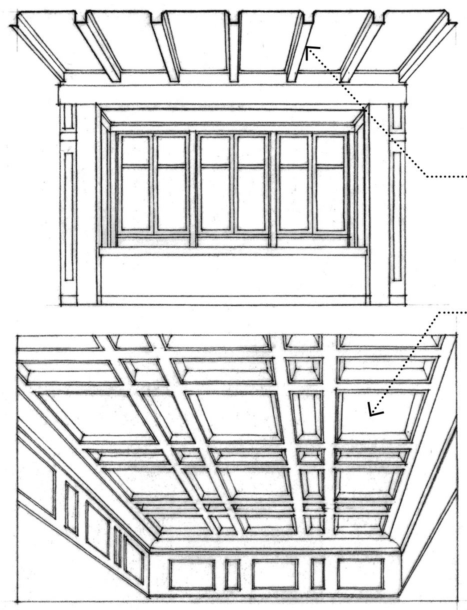
Dome
A vaulted structure having a circular plan and usually the form of a portion of a sphere, so constructed as to exert an equal thrust in all directions.





Truss
A structural frame based on the geometric rigidity of the triangle and composed of linear members subject only to axial tension or compression.

Ceiling

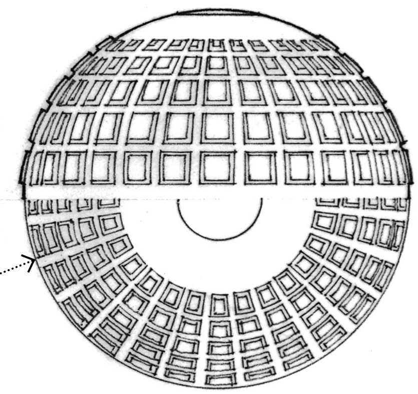


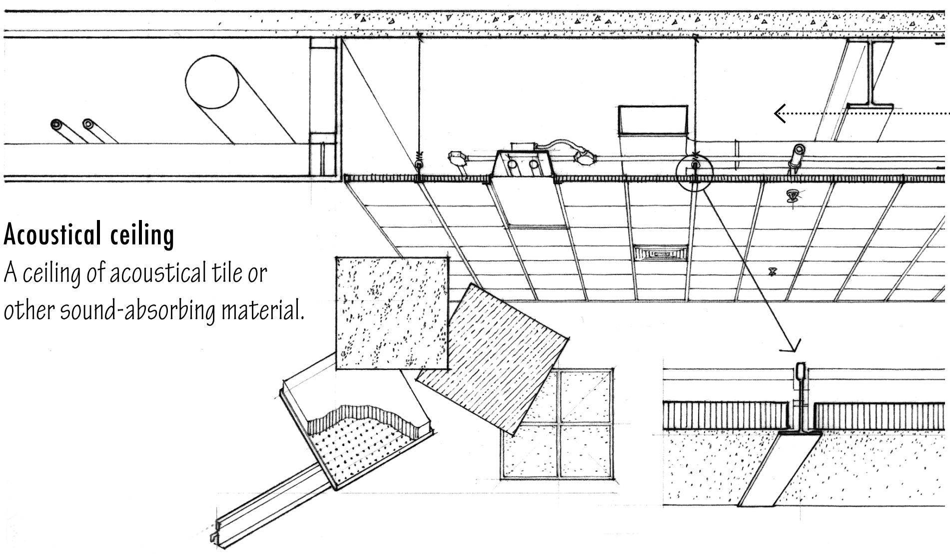
Ceiling
The overhead interior surface or lining of a room, often concealing the underside of the floor or roof above.

Beam ceiling
The underside of a floor showing the supporting beams and finished to form a ceiling.

Coffer
One of a number of recessed, usually square or octagonal panels in a ceiling, soffit, or vault. Also called caisson, lacunar.

Lacunar
A ceiling, soffit, or vault adorned with a pattern of recessed panels.



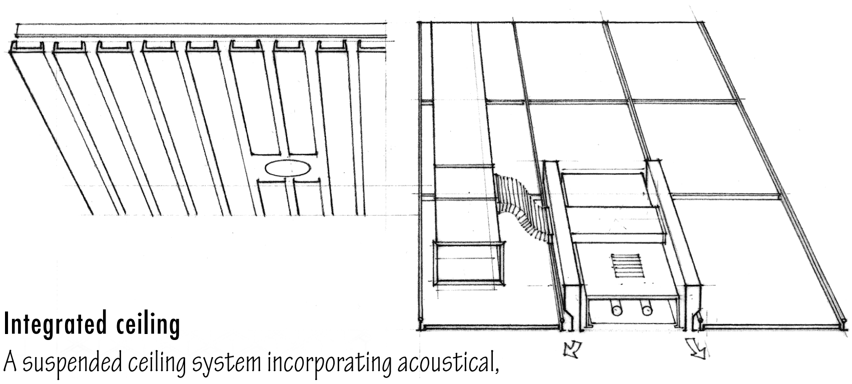


Plenum
The space between a suspended ceiling and the floor structure above, esp. one that serves as a receiving chamber for conditioned air to be distributed to inhabited spaces or for return air to be conveyed back to a central plant for processing.

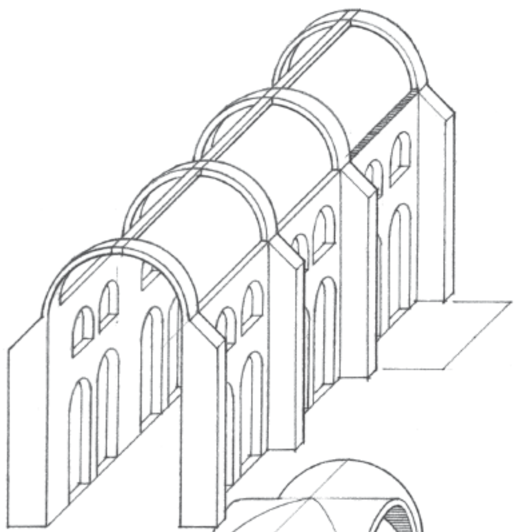
Acoustical ceiling
A ceiling of acoustical tile or other sound-absorbing material.

Suspended ceiling
A ceiling suspended from an overhead floor or roof structure to provide space for pipes, ductwork, lighting fixtures, or other service equipment.

Drop ceiling
A secondary ceiling formed to provide space for piping or ductwork, or to alter the proportions of a room. Also, dropped ceiling.

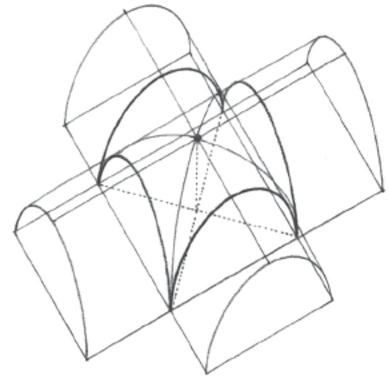


Integrated ceiling
A suspended ceiling system incorporating acoustical, lighting, and air-handling components into a unified whole.



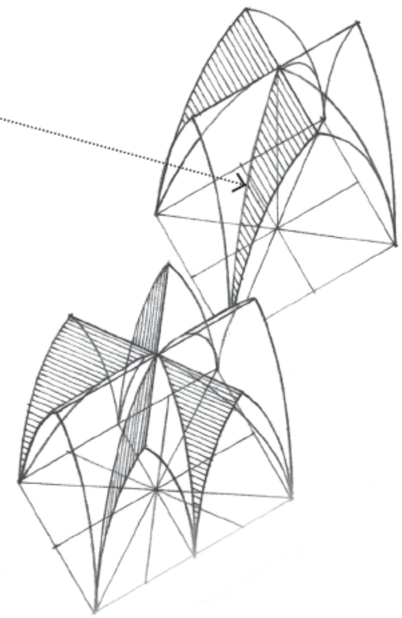
Vault
An arched structure of stone, brick, or reinforced concrete, forming a ceiling or roof over a hall, room, or other wholly or partially enclosed space.

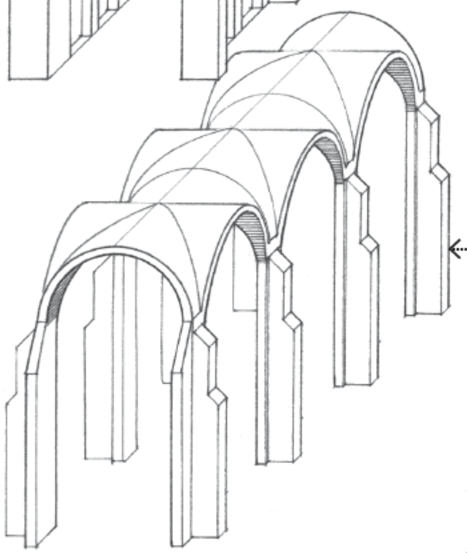
Since a vault behaves as an arch extended in a third dimension, the longitudinal supporting walls must be buttressed to counteract the thrusts of the arching action.



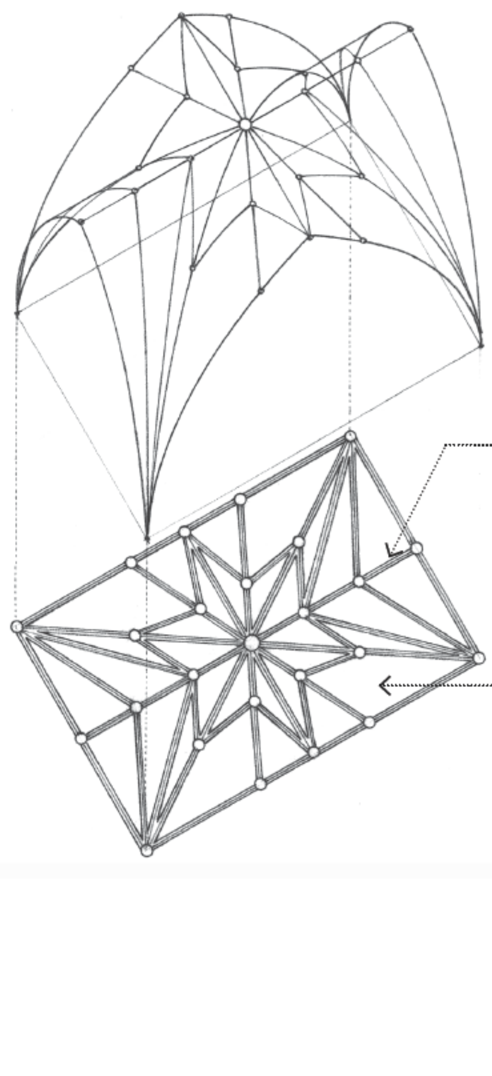
Barrel vault
A vault having a semicircular cross section.

Groin
One of the curved lines or edges along which two intersecting vaults meet.





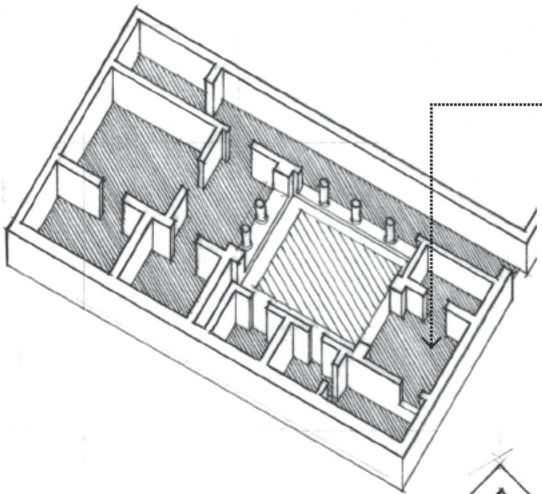
Buttress
An external support built to stabilize a structure by opposing its outward thrusts, esp. a projecting support built into or against the outside of a masonry wall.



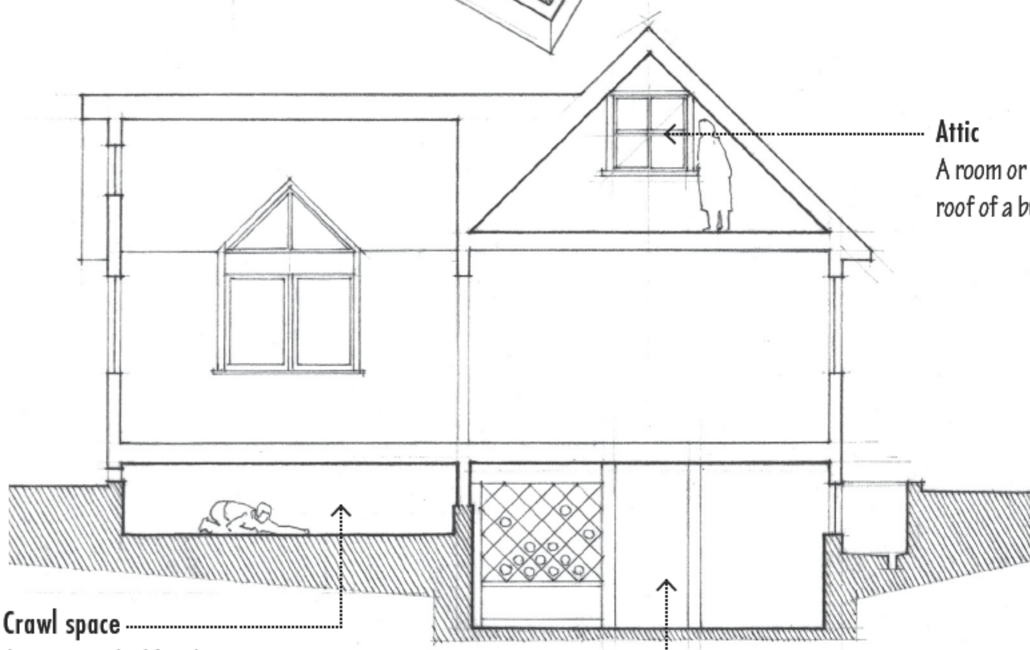
Rib
Any of several archlike members supporting a vault at the groins, defining its distinct surfaces or dividing these surfaces into panels.

Web
A surface framed by the ribs of a ribbed vault.

Room



Room
A portion of space within a building, separated by walls or partitions from other similar spaces.

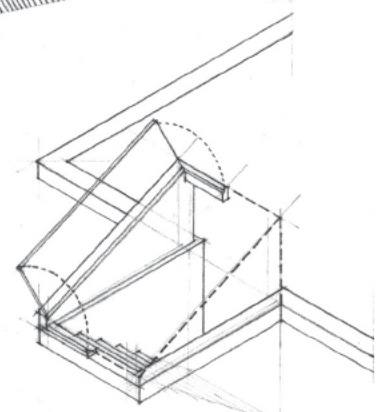


Attic
A room or space directly under the roof of a building, esp. a house.

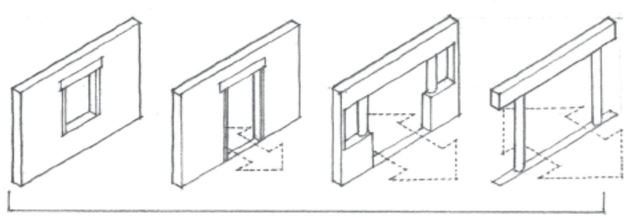
Crawl space
An area in a building having a clearance less than human height, but accessible by crawling, esp. such a space below the first floor that is enclosed by the foundation walls.

Cellar
A room or set of rooms for the storage of food, fuel, or the like, wholly or partly underground and usually beneath a building.

Storm cellar
A cellar or other underground place for shelter during violent storms, such as cyclones, tornadoes, or hurricanes. Also called cyclone cellar.

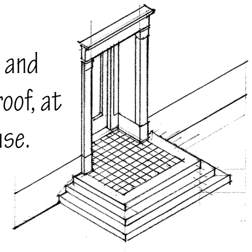


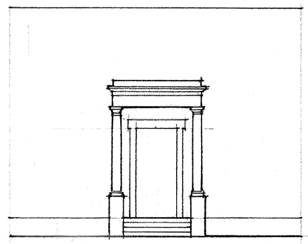
Bulkhead
A horizontal or inclined door over a stairway giving access to a cellar.



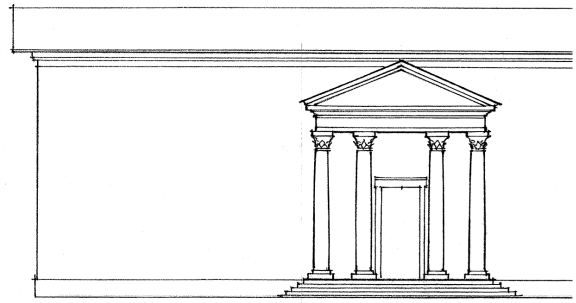
Transition
Movement, passage, or change from one form, state, or place to another.

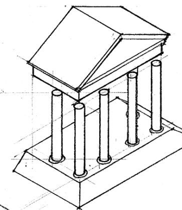
Stoop
A raised platform, approached by steps and sometimes having a roof, at the entrance of a house.



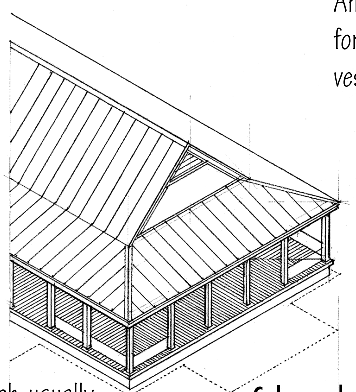


Porch
An exterior appendage to a building, forming a covered approach or vestibule to a doorway.

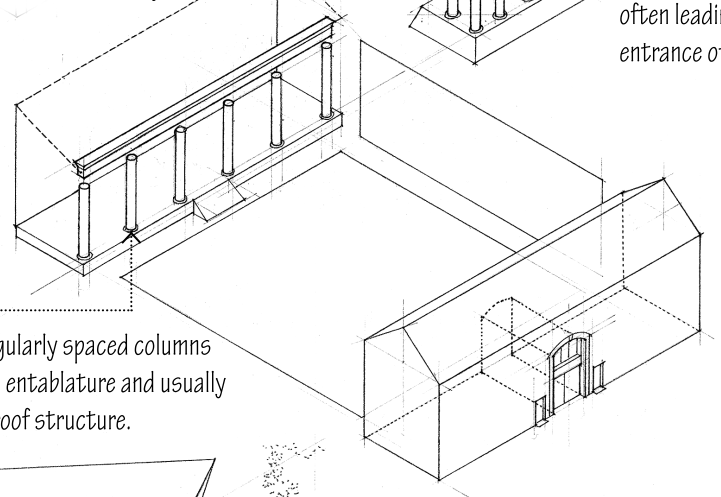




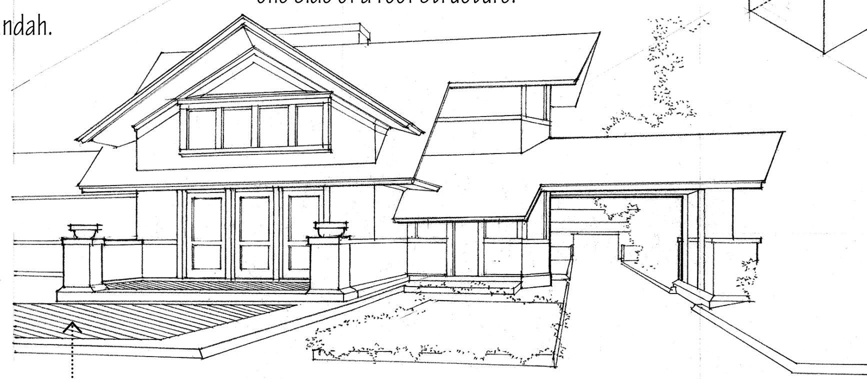
Portico
A porch having a roof supported by columns, often leading to the entrance of a building.



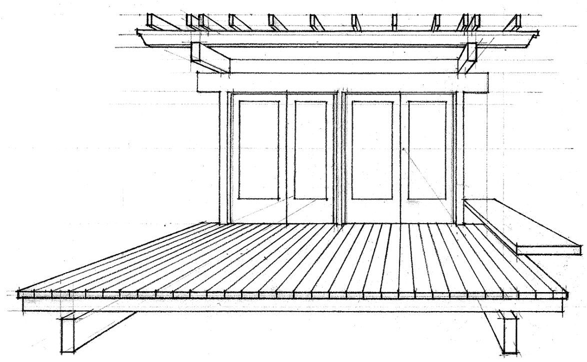
Veranda
A large, open porch, usually roofed and partly enclosed, as by a railing, often extending across the front and sides of a house. Also, verandah.



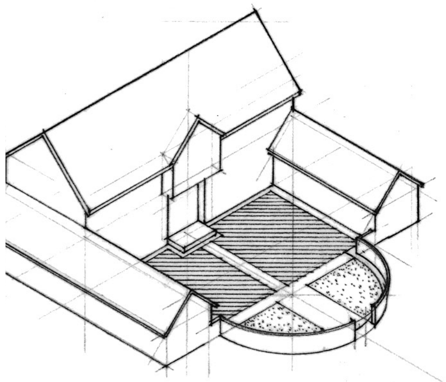
Colonnade
A series of regularly spaced columns supporting an entablature and usually one side of a roof structure.



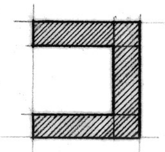
Terrace
An open, often paved area connected to a house or building and serving as an outdoor living area.

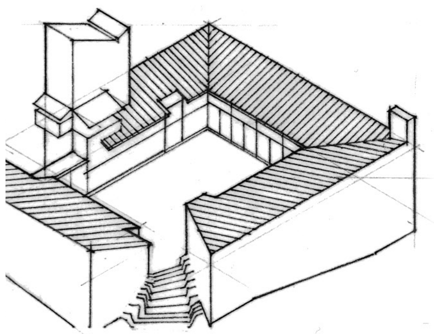


Deck
An open, unroofed porch or platform extending from a house or other building.



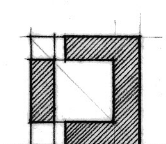
Court
An area open to the sky and mostly or entirely surrounded by walls or buildings.

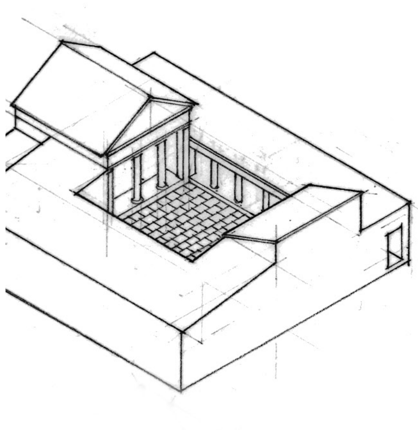




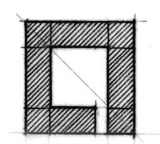
Courtyard
A court adjacent to or within a building, esp. one enclosed on all four sides.

Patio
A courtyard, esp. of a house, enclosed by low buildings, arcades, or walls.

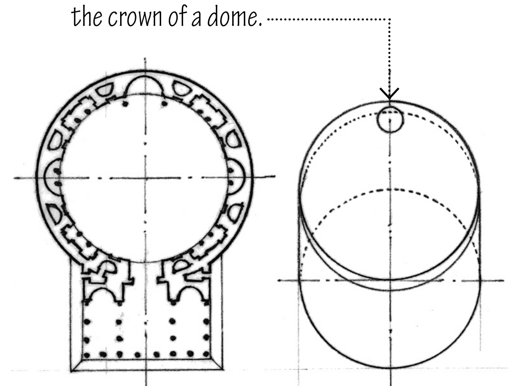




Atrium
A skylit, central court in a building, esp. a large interior one having a glass roof and surrounded by several stories of galleries.



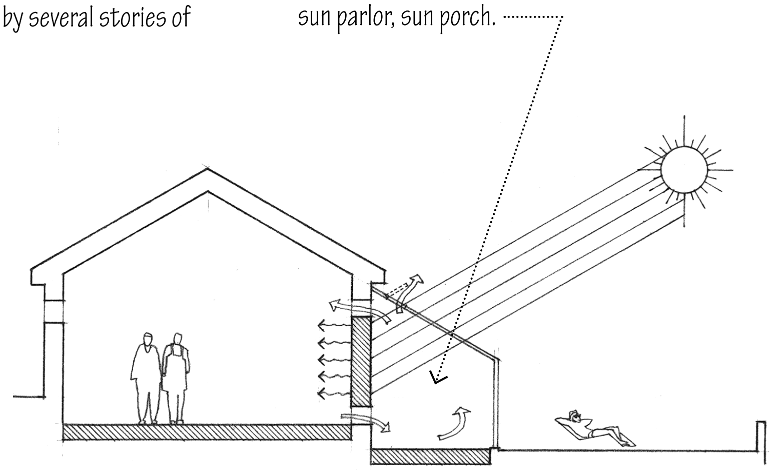
Oculus
A circular opening, esp. one at the crown of a dome.



Rotunda
A round, domed building, or a large and high circular space in such a building, esp. one surmounted by a dome.

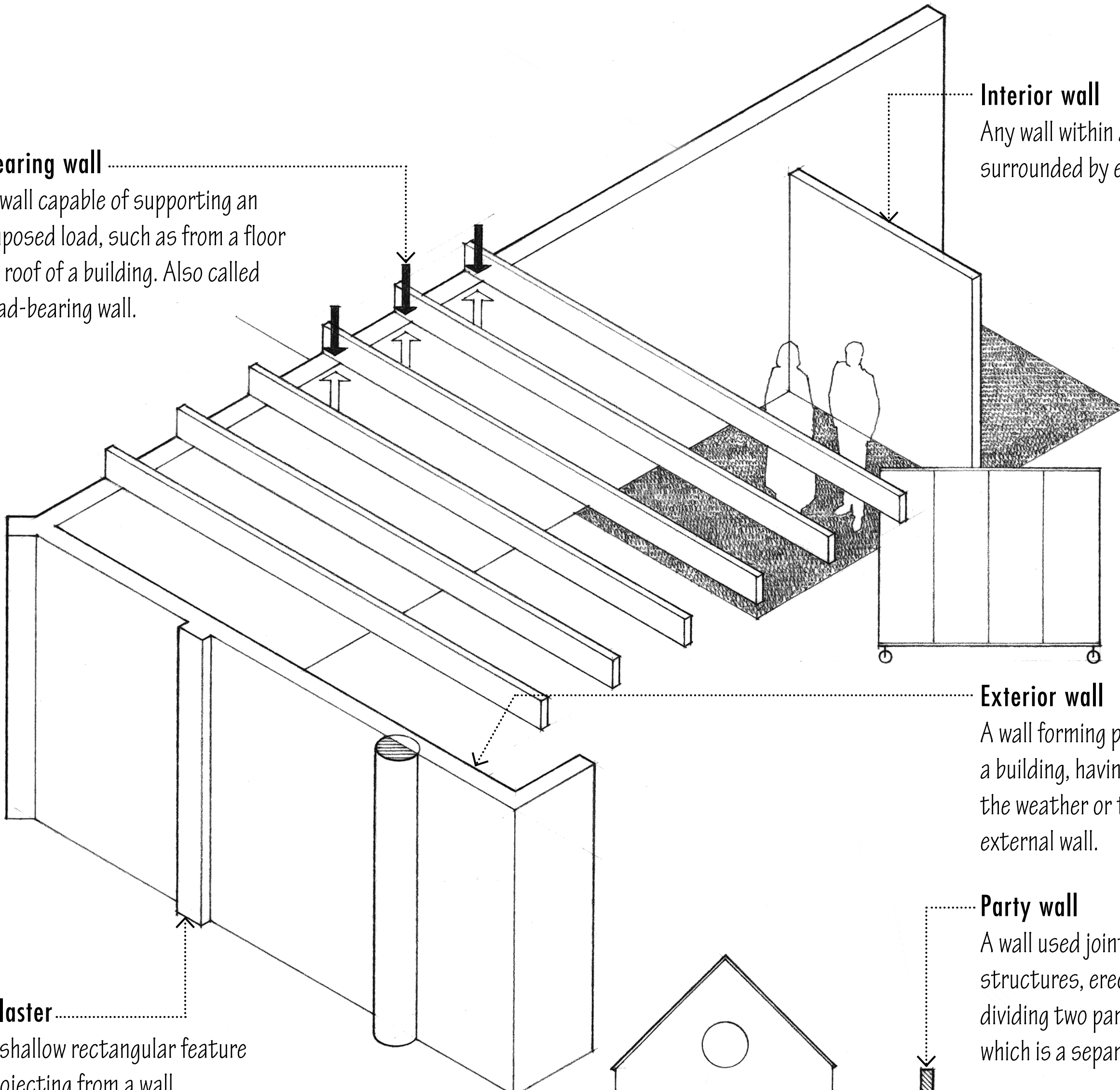
Solarium
A glass-enclosed porch, room, or gallery used for sunbathing or for therapeutic exposure to sunlight.

Sunroom
A glass-enclosed porch or room oriented to admit large amounts of sunlight. Also called sun parlor, sun porch.



Wall

Wall
Any of various upright constructions presenting a continuous surface and serving to enclose, divide, or protect an area.

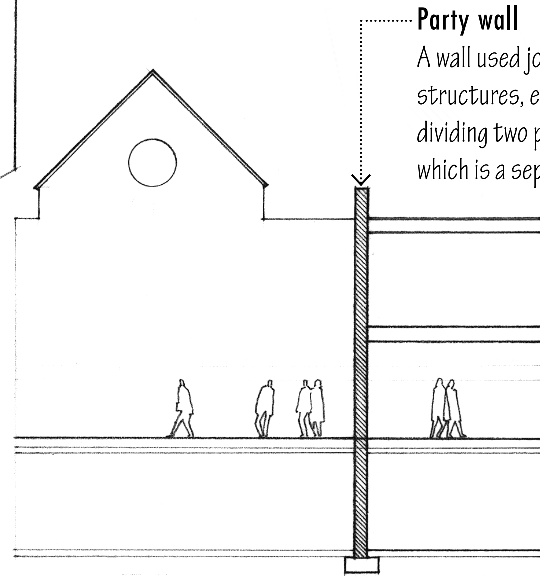


Interior wall
Any wall within a building, entirely surrounded by exterior walls.

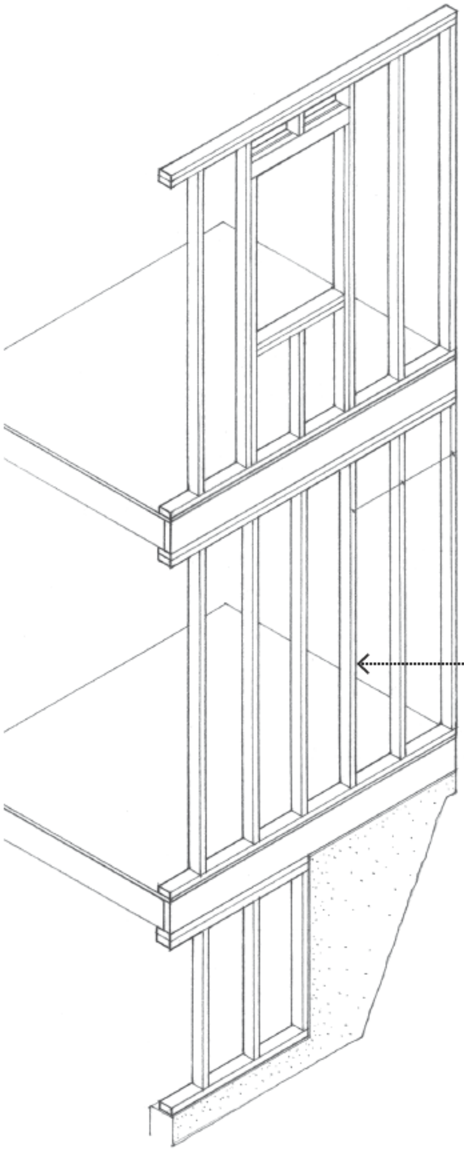
Bearing wall
A wall capable of supporting an imposed load, such as from a floor or roof of a building. Also called load-bearing wall.

Exterior wall
A wall forming part of the envelope of a building, having one face exposed to the weather or to earth. Also called external wall.

Pilaster
A shallow rectangular feature projecting from a wall, architecturally treated as a column.

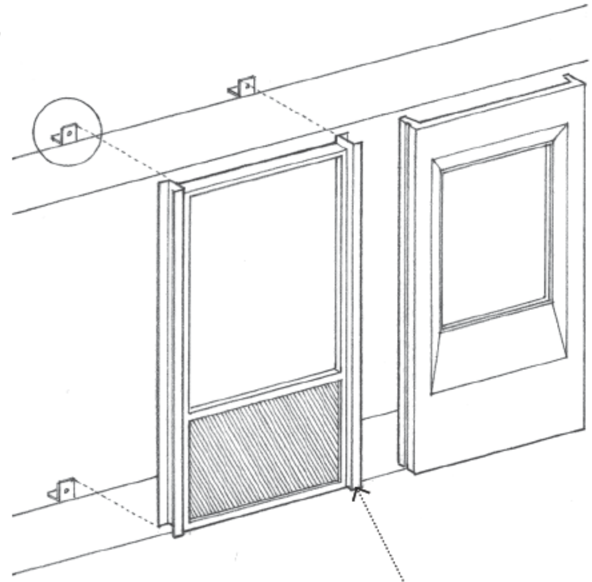


Party wall
A wall used jointly by contiguous structures, erected upon a line dividing two parcels of land, each of which is a separate real-estate entity.



Shell

The exterior framework or walls and roof of a building.

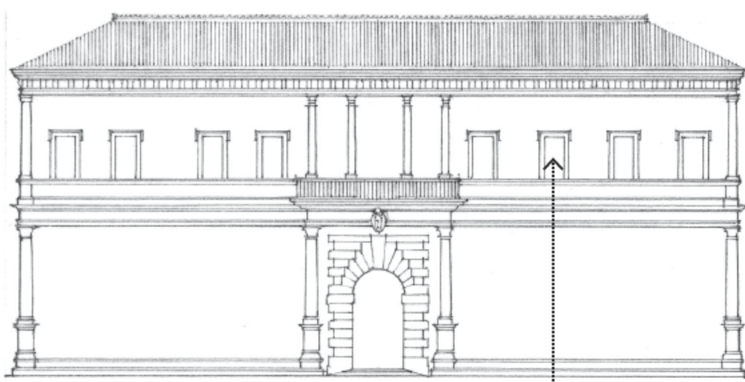


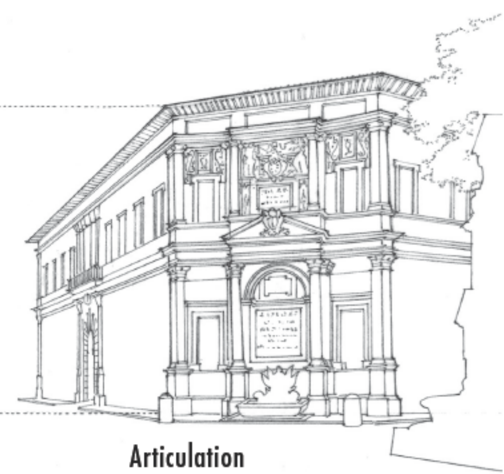
Stud

Any of a repetitive series of slender, upright members of wood or light-gauge metal forming the structural frame of a wall or partition.

Curtain wall

An exterior wall supported wholly by the structural frame of a building and carrying no loads other than its own weight and wind loads.





Facade

The front of a building or any of its sides facing a public way or space, esp. one distinguished by its architectural treatment.

Fenestration

The design, proportioning, and disposition of windows and other exterior openings of a building.

Articulation

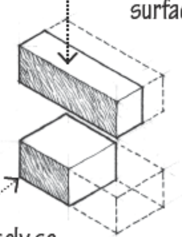
A method or manner of jointing that makes the united parts clear, distinct, and precise in relation to each other.

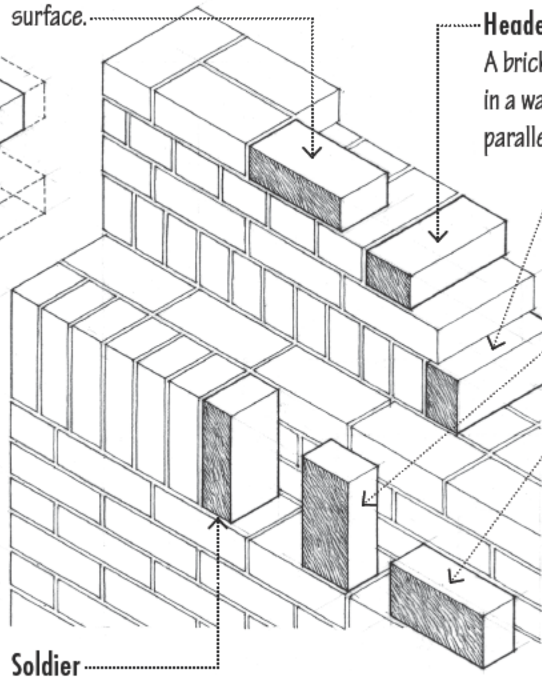
Brick

Soap
A brick or tile having normal face dimensions but a nominal thickness of 2 in. (51).

Stretcher
A brick or other masonry unit laid horizontally in a wall with the longer edge exposed or parallel to the surface.

Brick
A masonry unit of clay formed into a rectangular prism while plastic and hardened by drying in the sun or firing in a kiln.





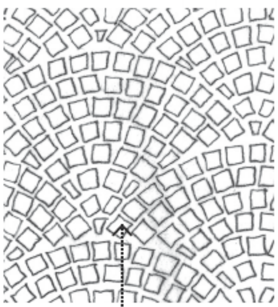
Header
A brick or other masonry unit laid horizontally in a wall with the shorter end exposed or parallel to the surface.

Rowlock
A brick laid horizontally on the longer edge with the shorter end exposed. Also, rollock.

Sailor
A brick laid vertically with the broad face exposed.

Shiner
A brick laid horizontally on the longer edge with the broad face exposed. Also called bull stretcher.

Bat
A brick cut transversely so as to leave one end whole.



Clinker
A dense, hard-burned brick used esp. for paving.

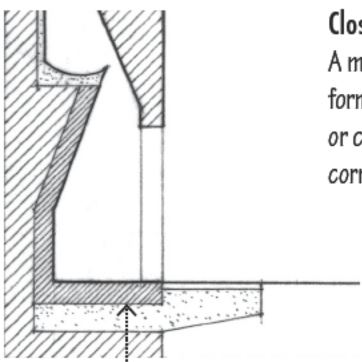
Soldier
A brick laid vertically with the longer face edge exposed.

Soldier course
A continuous course of soldiers in brickwork.

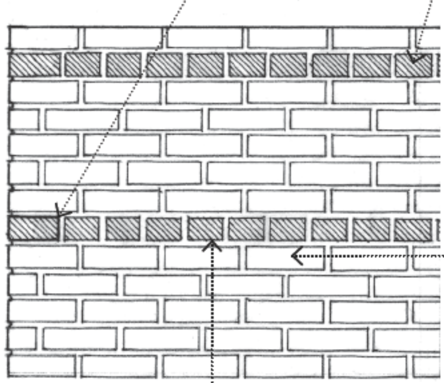
Closer
A masonry unit specially formed or cut to finish a course or complete the bond at the corner of a wall. Also, closure.

Flare header
A brick having a darker end exposed as a header in patterned brickwork.

Common brick
Brick made for general building purposes and not specially treated for color and texture. Also called building brick.



Firebrick
A brick made of fire clay and used for lining furnaces and fireplaces.

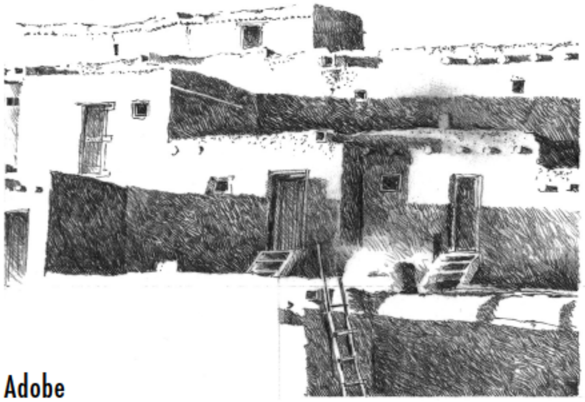


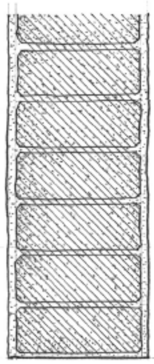
Facing brick
Brick made of special clays for facing a wall, often treated to produce the desired color and surface texture. Also called face brick.

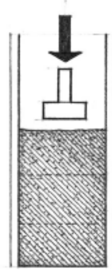
Stretching course
A continuous course of stretchers in brickwork.

Bond
Any of various arrangements of masonry units having a regular, recognizable, usually overlapping pattern to increase the strength and enhance the appearance of the construction.

Heading course
A continuous course of headers in brickwork.

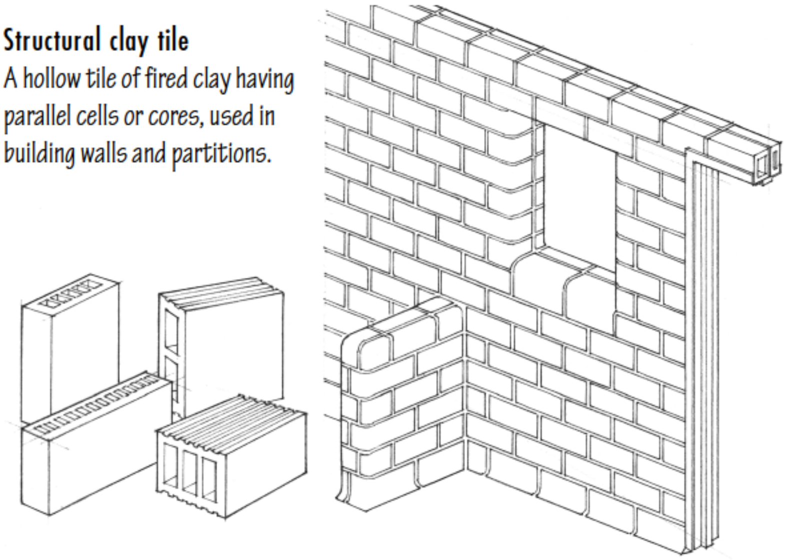




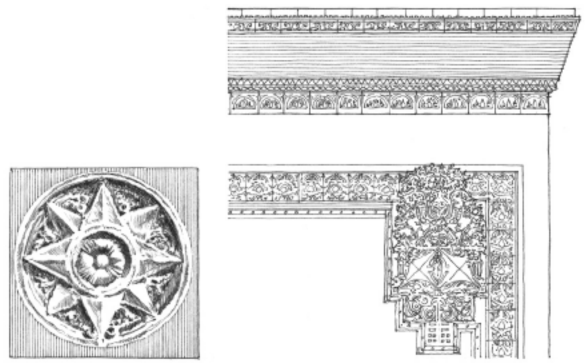


Rammed earth
A stiff mixture of clay, sand or other aggregate, and water, compressed and dried within forms as a wall construction. Also called pisé, pisay, pisé de terre.

Adobe
Sun-dried brick made of clay and straw, commonly used in regions with little rainfall.



Structural clay tile
A hollow tile of fired clay having parallel cells or cores, used in building walls and partitions.

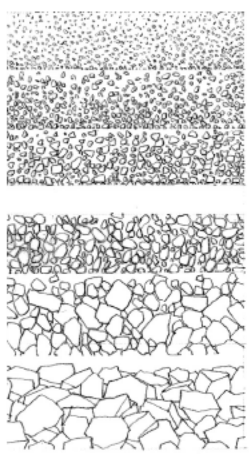


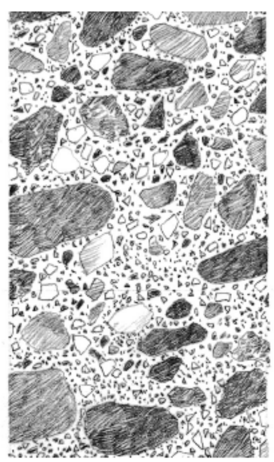
Terra cotta
A hard, fired clay, reddish-brown in color when unglazed, used for architectural facings and ornaments, tile units, and pottery.

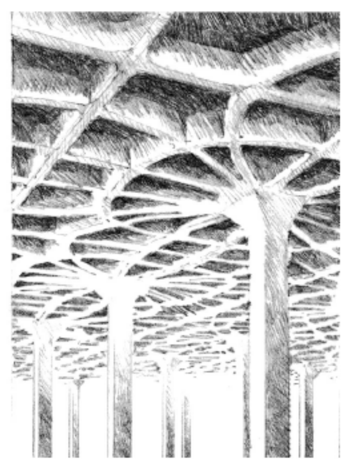
Cement
A calcined mixture of clay and limestone, finely pulverized and used as an ingredient in concrete and mortar. The term is frequently used incorrectly for concrete.

Concrete
An artificial, stonelike building material made by mixing cement and various mineral aggregates with sufficient water to cause the cement to set and bind the entire mass.

Aggregate
Any of various hard, inert, mineral materials, such as sand and gravel, added to a cement paste to make concrete or mortar. Since aggregate represents from 60% to 80% of the concrete volume, its properties are important to the strength, weight, and fire resistance of the hardened concrete. Aggregate should be hard, dimensionally stable, and free of clay, silt, and organic matter, which can prevent the cementing matrix from binding the particles together.





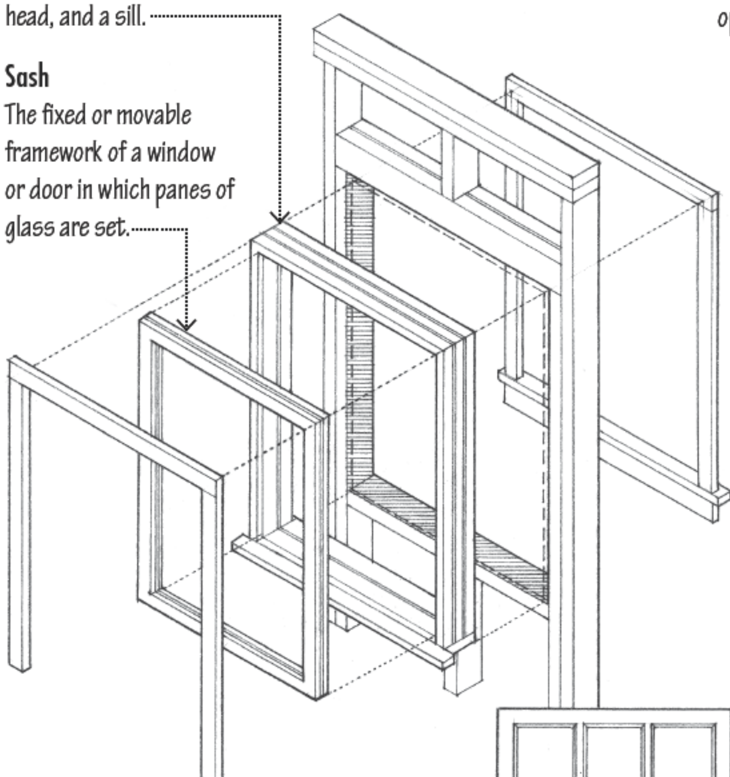


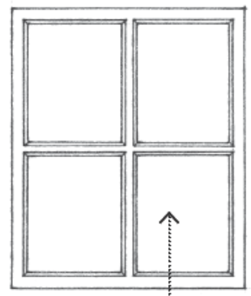
Window

Window
An opening in the wall of a building for admitting light and air, usually fitted with a frame in which are set operable sashes containing panes of glass.

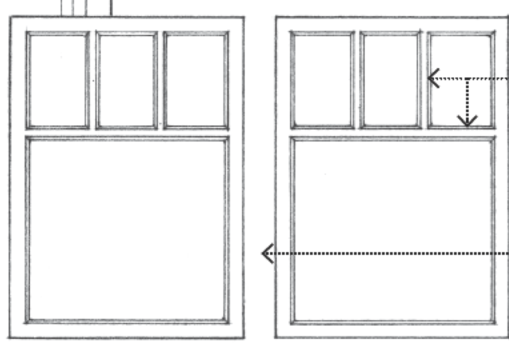
Window frame
The fixed frame of a window, consisting of two jambs, a head, and a sill.

Sash
The fixed or movable framework of a window or door in which panes of glass are set.



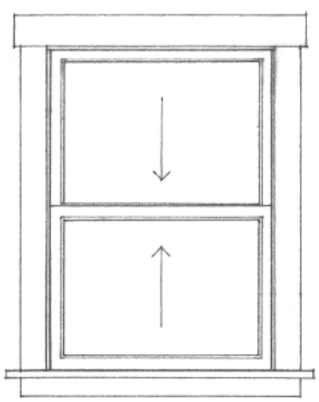


Pane
One of the divisions of a window or door, consisting of a single unit of glass.

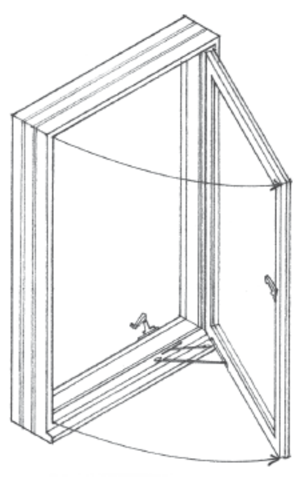


Muntin
A rabbeted member for holding the edges of windowpanes within a sash. Also called glazing bar, sash bar.

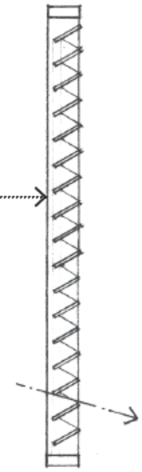
Mullion
A vertical member between the lights of a window.



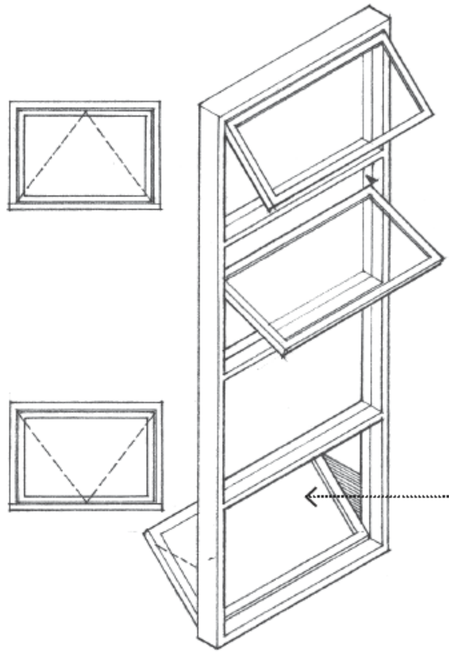
Double-hung window
A window having two vertically sliding sashes, each in separate grooves or tracks and closing a different part of the window.



Casement window
A window with at least one casement, often used in combination with fixed lights.

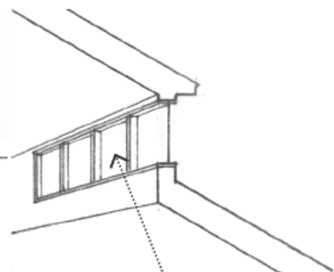


Louver
An opening fitted with slanting, fixed or movable slats to admit air but exclude rain and snow or to provide privacy. Also, louvre.

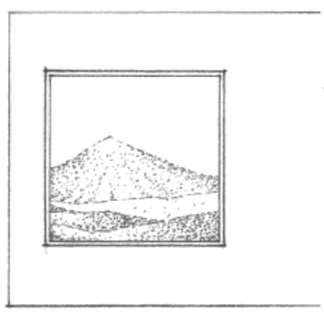


Awning window
A window having one or more sashes swinging outward on hinges generally attached to the top of the frame.

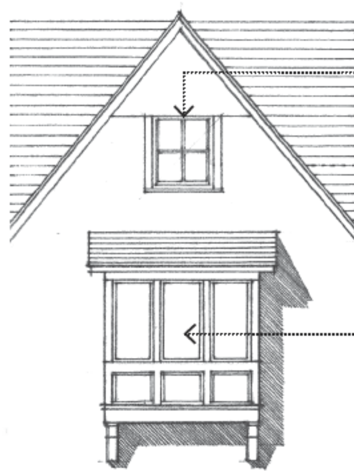
Hopper window
A window having one or more sashes swinging inward on hinges generally attached on the bottom. Also called hospital window.



Clerestory
A portion of an interior rising above adjacent rooftops and having windows admitting daylight to the interior. Also, clearstory.

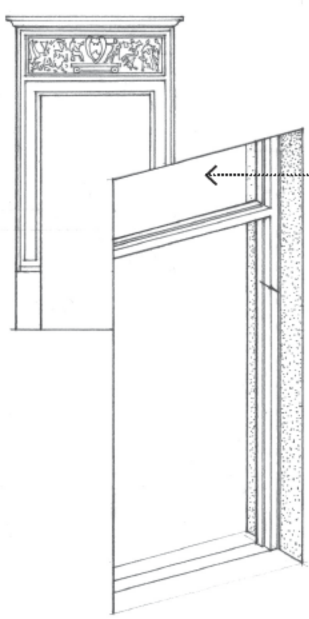


Picture window
A large, usually fixed single-pane window, placed to frame an attractive exterior view.

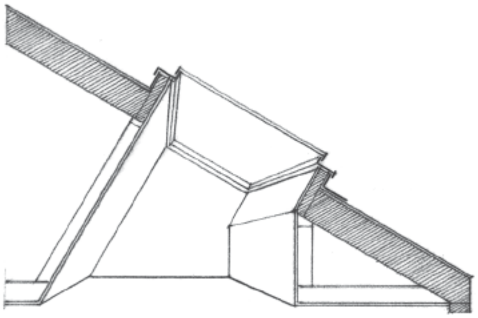


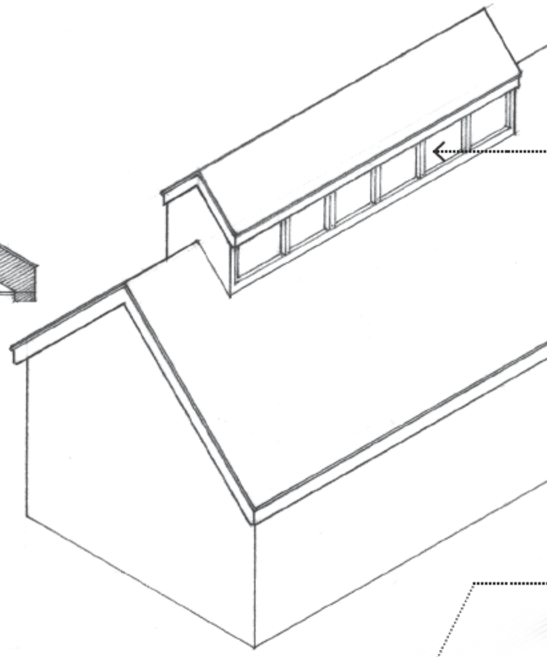
Gable window
A window in or under a gable.

Bay window
A window or series of windows projecting outward from the main wall of a building and forming an alcove in a room within.



Transom window
A window above the transom of a doorway. Also called transom, transom light.

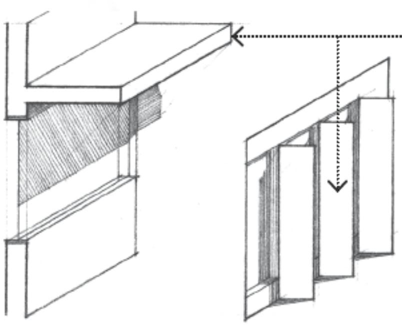




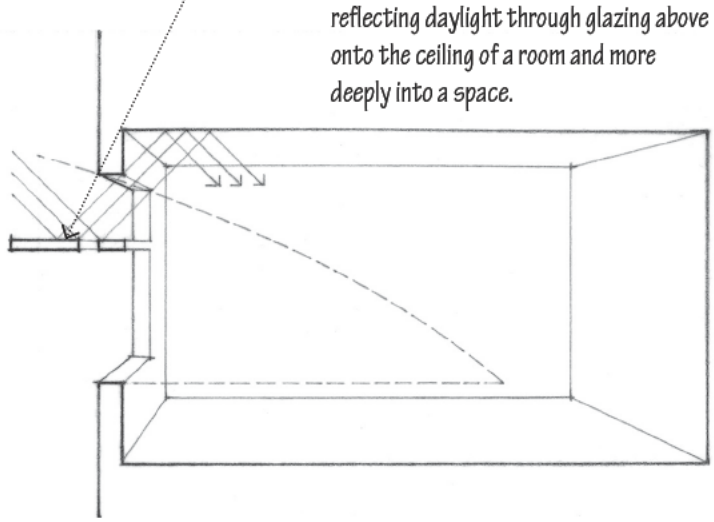
Monitor
A raised construction straddling the ridge of a roof, having windows or louvers for lighting or ventilating a building.

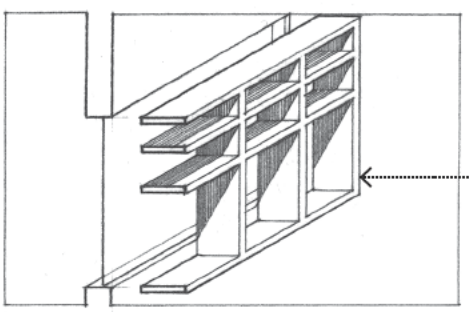
Skylight
An opening in a roof or ceiling, glazed with a transparent or translucent material, for admitting daylight.

Light shelf
A horizontal overhang that shades glazing from direct sunlight below while reflecting daylight through glazing above onto the ceiling of a room and more deeply into a space.

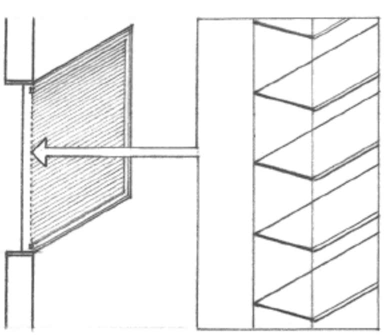


Sunshade
Any of various exterior devices consisting of fixed horizontal or vertical fins angled to shield a window from direct sunlight.





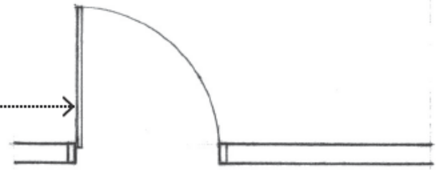
Brise-soleil
A screen, usually of louvers, placed on the outside of a building to shield the windows from direct sunlight.



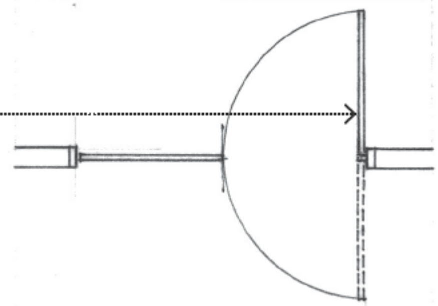
Solar screen
A panel of miniature external louvers for shading a window from direct sunlight and glare while allowing a high degree of visibility, daylighting, ventilation, visual daytime privacy, and insect protection.

Door

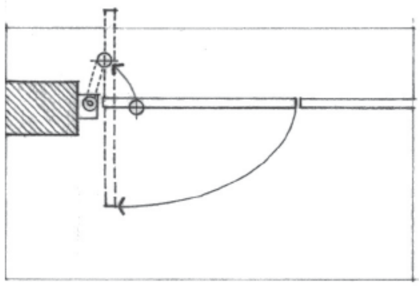
Door
A hinged, sliding, or folding barrier of wood, metal, or glass for opening and closing an entrance to a building, room, or cabinet.



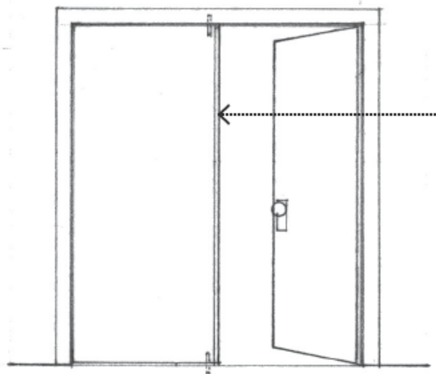
Single-acting door
A door hung on hinges that permit it to swing in one direction only.



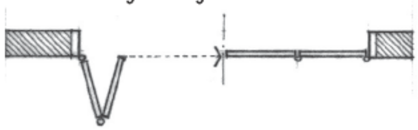
Double-acting door
A door hung on hinges that permit it to swing in either direction from a closed position.



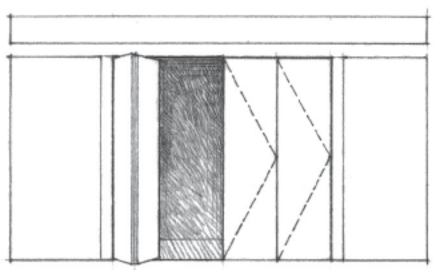
Pivoted door
A door carried on and swinging about on a center or offset pivot, as distinguished from one hung on hinges.



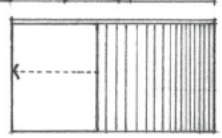
Double doors
A pair of doors hung in the same doorframe.



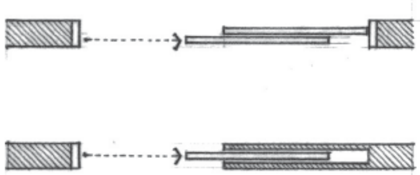
Bifold door
A folding door that divides into two leaves, the inner edge of each leaf being hung from an overhead track and the outer edges pivoted at the jamb.



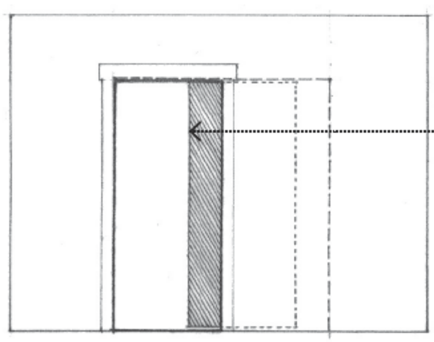
Folding door
A door with hinged sections that can be folded flat against one another when opened.



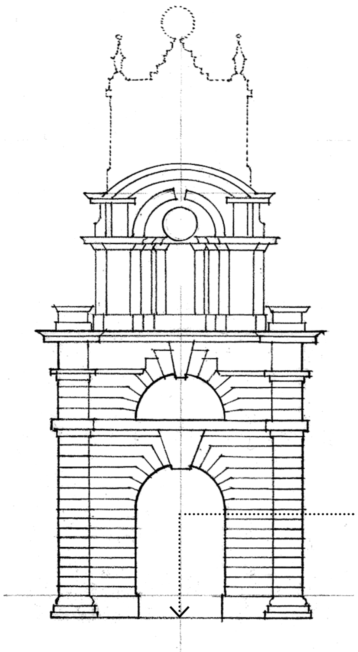
Accordion door
A multi-leafed door that is hung from an overhead track and opens by folding back in the manner of an accordion.



Sliding door
A door that operates or moves by sliding on a track, usually parallel to a wall.

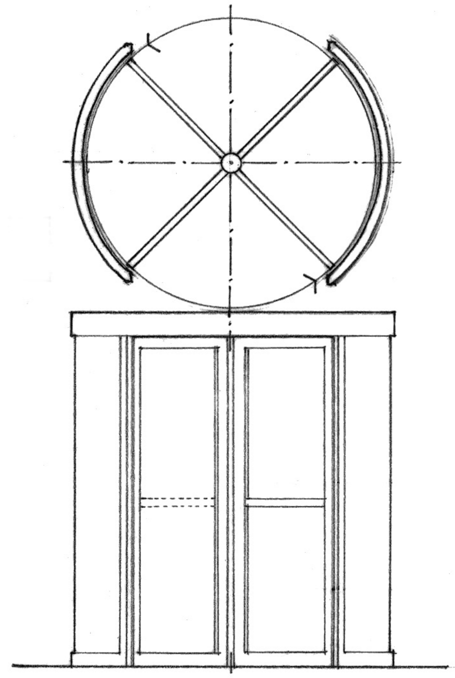


Pocket door
A door that slides into and out of a recess in a doorway wall.

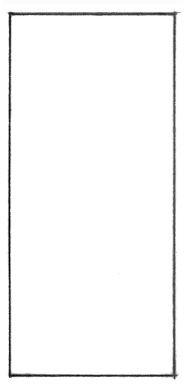


Portal
A doorway, gate, or entrance, esp. an imposing one emphasized by size and stately architectural treatment.

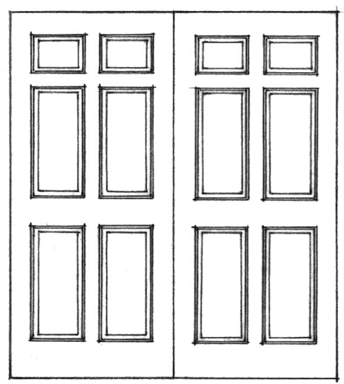
Threshold
A place or point of entering or beginning.



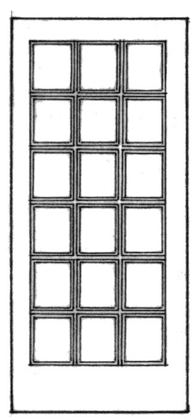
Revolving door
An entrance door for excluding drafts from the interior of a building, consisting of four leaves set in the form of a cross and rotating about a central, vertical pivot within a cylindrically shaped vestibule. Some revolving doors automatically fold back in the direction of egress when pressure is applied, providing a legal passageway on both sides of the door pivot.



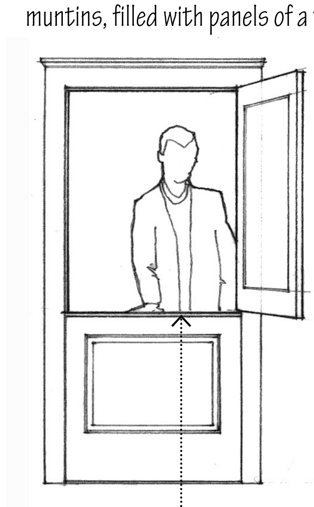
Flush door
A door having smooth-surfaced faces.



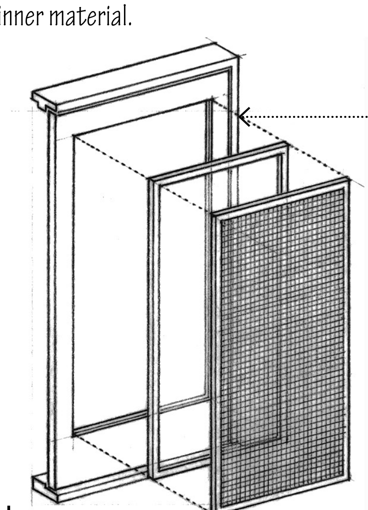
Paneled door
A door having a fremework of stiles, rails, and sometimes muntins, filled with panels of a thinner material.



French door
A door having rectangular glass panes extending throughout its length, and often hung in pairs. Also called casement door.



Dutch door
A door divided horizontally so that the upper or lower part can be opened or closed separately.



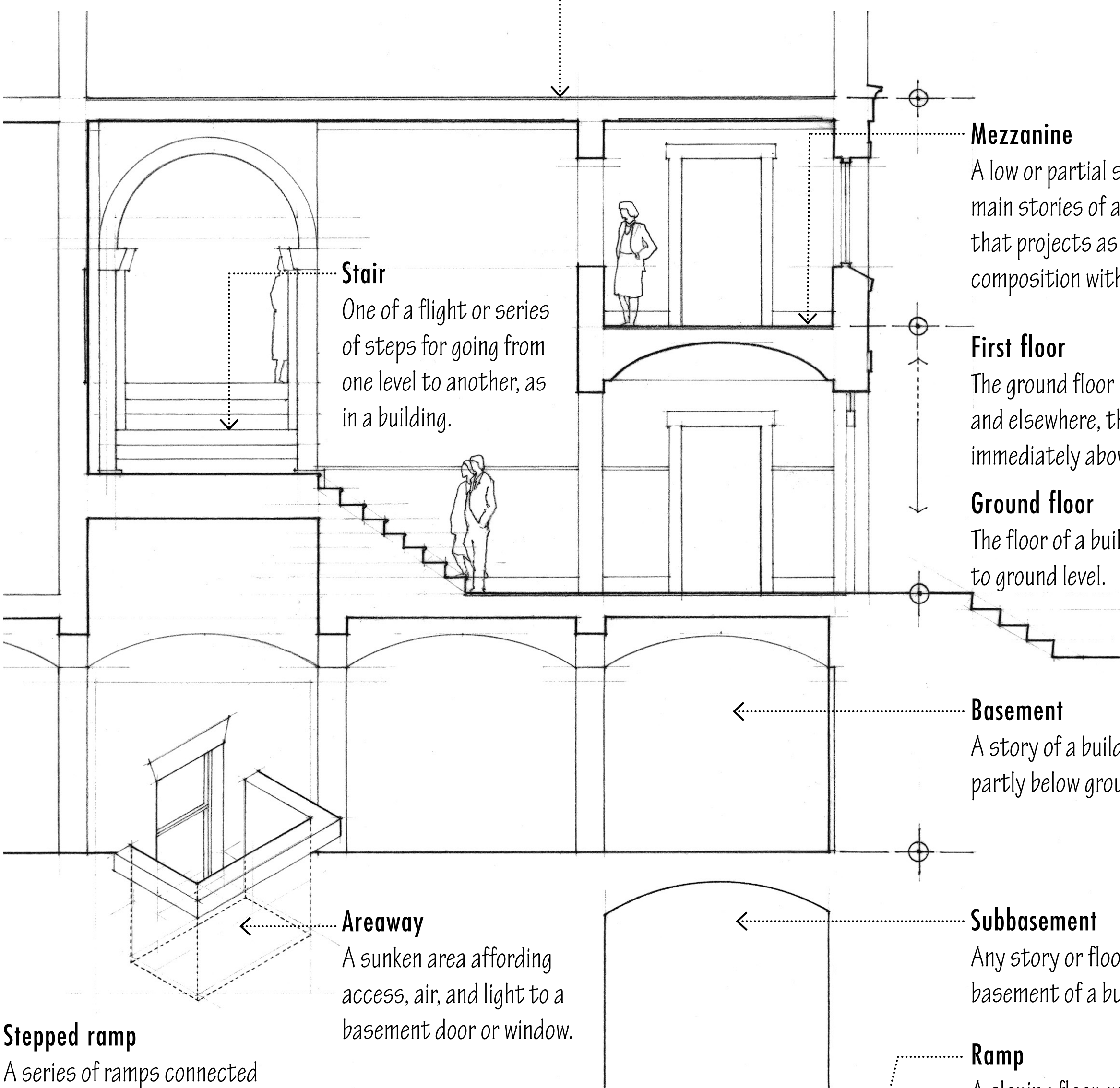
Combination door
An exterior door having a frame into which different types of panels can be inserted, such as a screen for summer or storm sash for winter.

Screen door
An exterior door having wood or aluminum stiles and rails that hold a wire or plastic mesh to admit air but exclude insects.

Floor

Piano nobile
The principal story of a large building, such as a palace or villa, with formal reception and dining rooms, usually one flight above the ground floor.

Floor
A continuous supporting surface extending horizontally throughout a building, having a number of rooms and constituting one level in the structure.



Mezzanine
A low or partial story between two main stories of a building, esp. one that projects as a balcony and forms a composition with the story beneath it.

Stair
One of a flight or series of steps for going from one level to another, as in a building.

First floor
The ground floor of a building. In Britain and elsewhere, the first floor is the floor immediately above the ground floor.

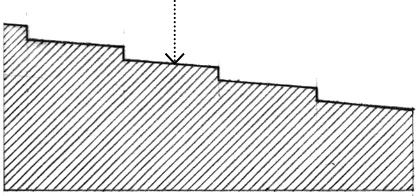
Ground floor
The floor of a building at or nearest to ground level.

Basement
A story of a building that is wholly or partly below ground level.

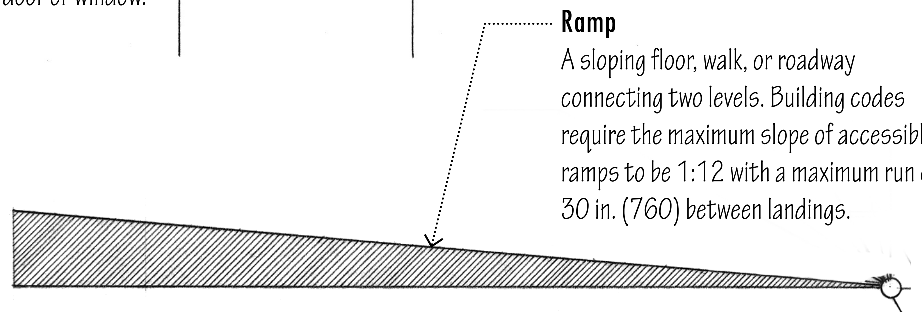
Areaway
A sunken area affording access, air, and light to a basement door or window.

Subbasement
Any story or floor below the main basement of a building.

Stepped ramp
A series of ramps connected by steps.



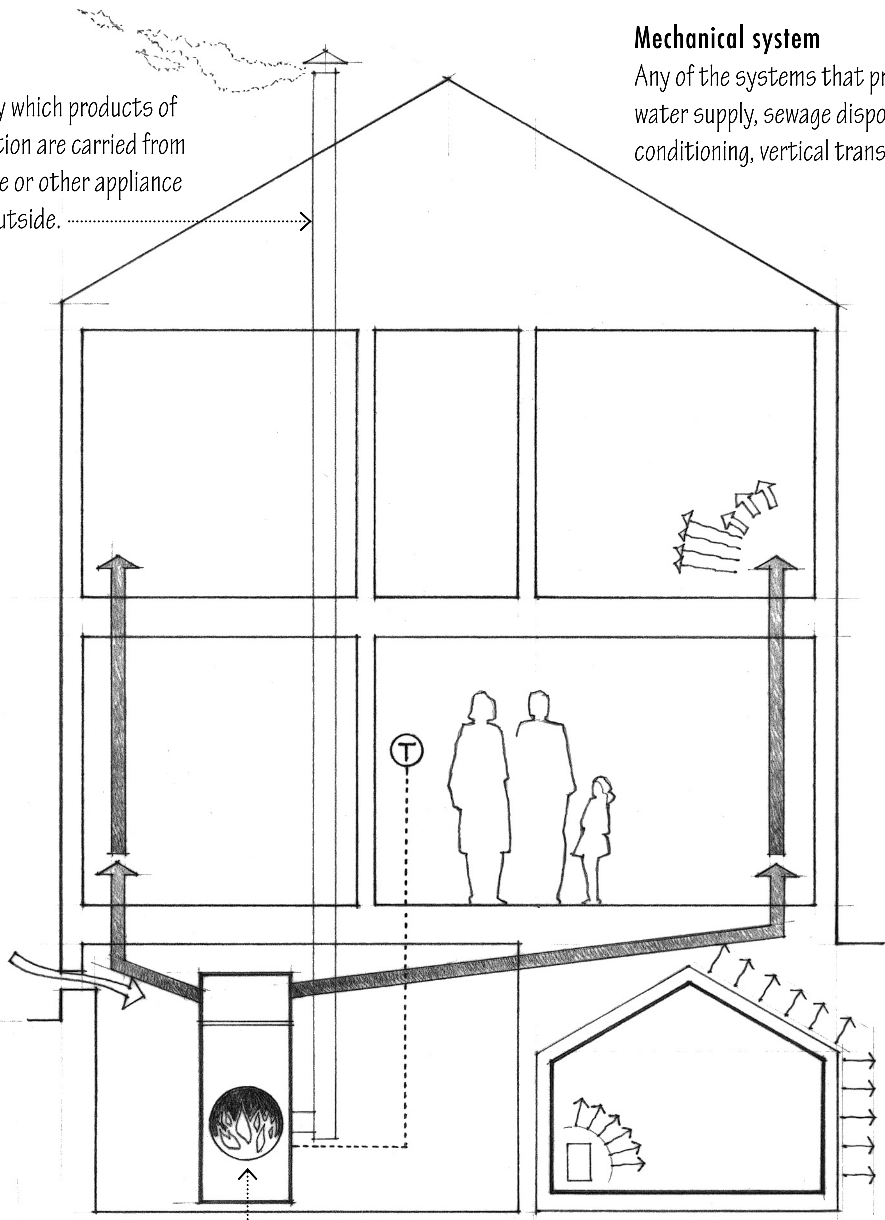
Ramp
A sloping floor, walk, or roadway connecting two levels. Building codes require the maximum slope of accessible ramps to be 1:12 with a maximum run of 30 in. (760) between landings.



Mechanical, Electrical, Plumbing Systems

Mechanical system
Any of the systems that provide essential services to a building, such as water supply, sewage disposal, electric power, heating, ventilation, air-conditioning, vertical transportation, or fire fighting.

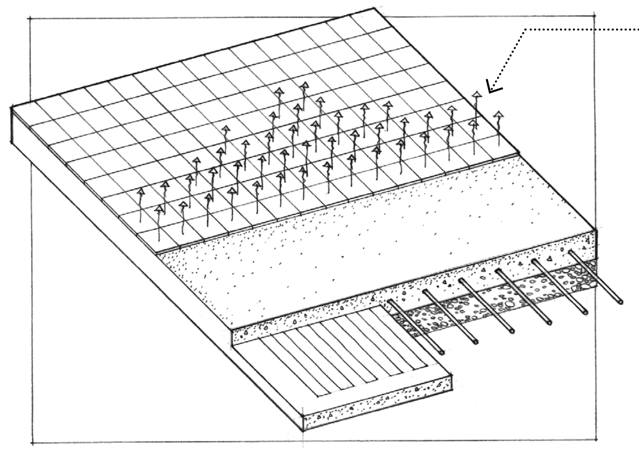
Vent
A pipe by which products of combustion are carried from a furnace or other appliance to the outside.



Central heating
A mechanical system that supplies heat to an entire building from a single source through a network of ducts or pipes.

Heating load
The hourly rate of net heat loss in an enclosed space, expressed in Btu per hour and used as the basis for selecting a heating unit or system.

Furnace
An apparatus in which heat is produced, as for heating a house or producing steam.

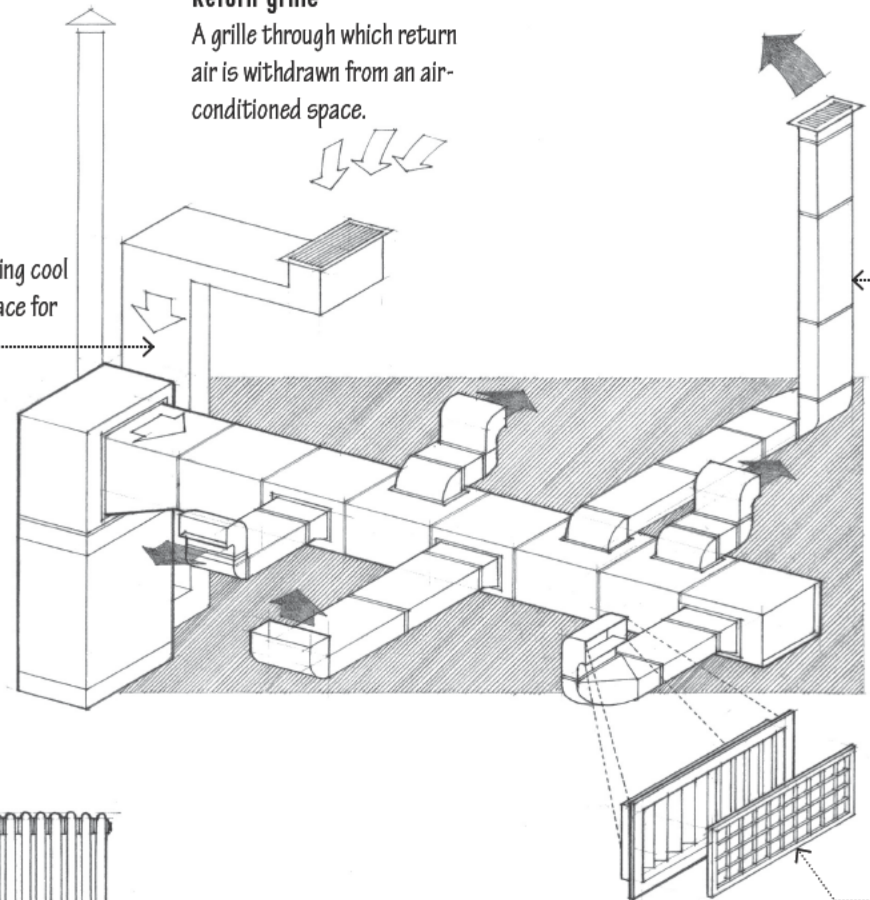


Radiant heating
A system for heating by radiation from a surface, esp. one that is heated by means of electric resistance or hot water.

Electric heat
Heat generated by the resistance of a conductor to the flow of electric current.

Return grille
A grille through which return air is withdrawn from an air-conditioned space.

Forced warm-air heating
A system for heating a building by means of air heated in a furnace and distributed by a fan through ductwork to registers or diffusers.



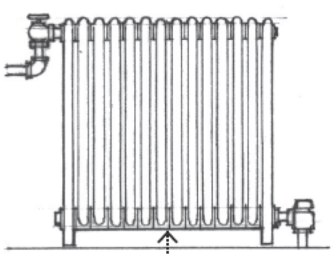
Cold-air return
A duct for conveying cool air back to a furnace for reheating.

Duct
A pipe or conduit of sheet metal or fiberglass for conducting heated or conditioned air. Also called air duct.

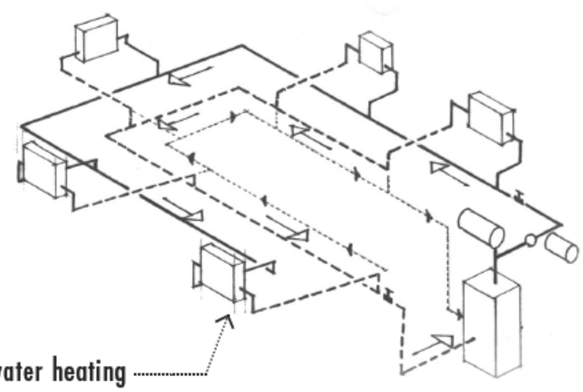
Ductwork
A system of ducts, connectors, and dampers for conveying air in a heating, ventilating, or air-conditioning system. Also called ducting.

Chase
A continuous space or recess built into a wall or through a floor for pipes or ducts.

Grille
A grating or perforated screen for covering, concealing, or protecting a wall, floor, or ceiling opening.

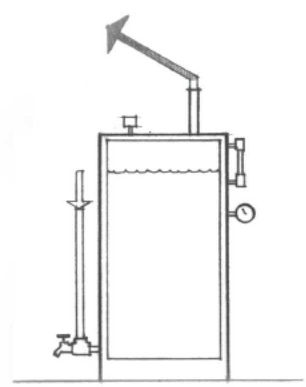


Radiator
A heating device consisting of a series or coil of pipes through which hot water or steam passes.

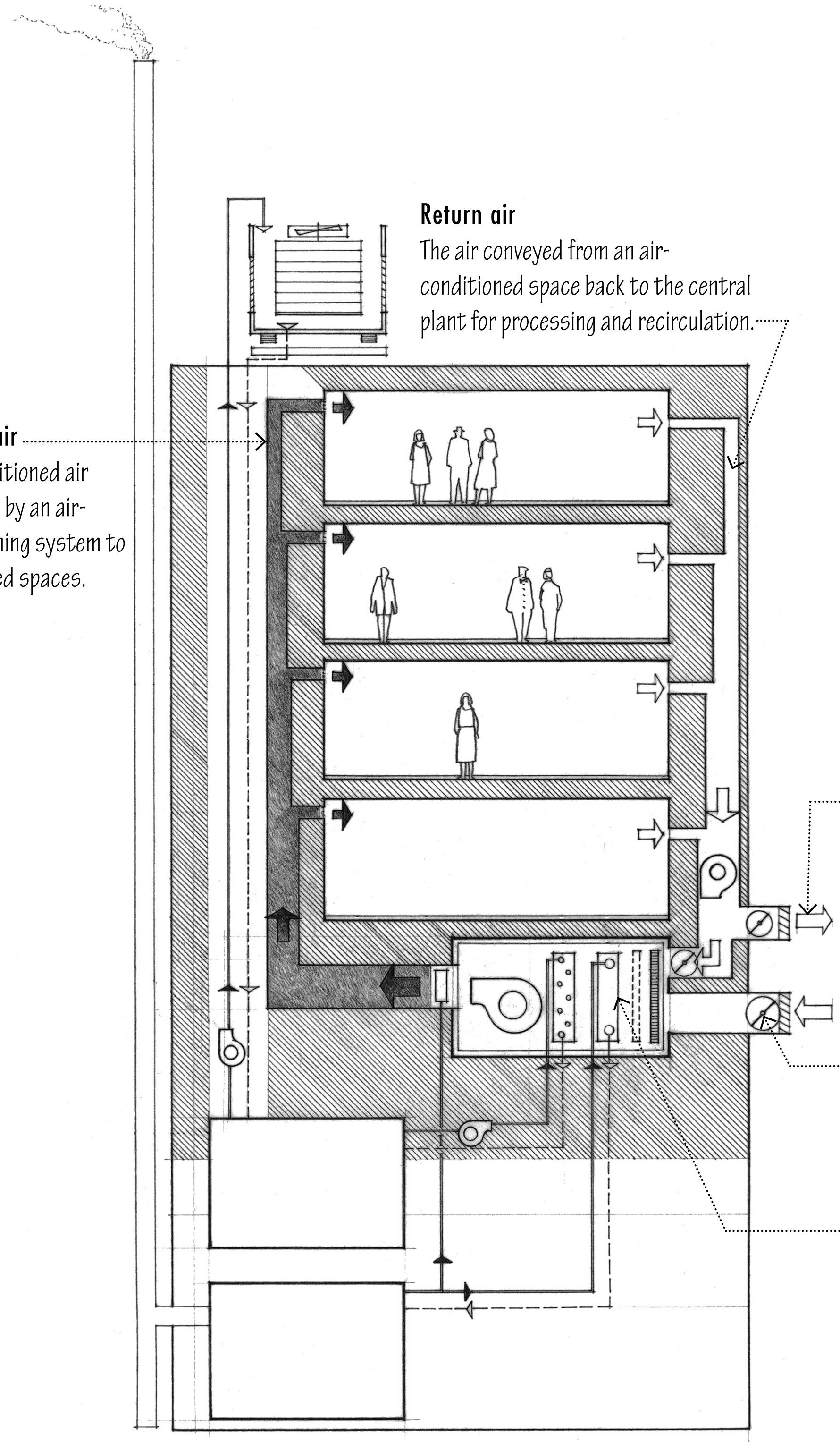


Hot-water heating
A system for heating a building by means of water heated in a boiler and circulated by a pump through pipes to radiators or convectors. Also called hydronic heating.

Steam heating
A system for heating a building by means of steam generated in a boiler and circulated through pipes to radiators.



Boiler
A closed vessel or arrangement of vessels and tubes in which water is heated or steam is generated to supply heat or power.



Air conditioner
Any device or apparatus for controlling, esp. lowering, the temperature and humidity of a space.

Central air conditioning
An air-conditioning system that treats air at a central location and distributes the conditioned air to an entire building by means of fans and ductwork.

HVAC
Acronym for heating, ventilating, and air conditioning.

Heat exchanger
A device for transferring the heat of a fluid flowing on one side of a barrier to a fluid flowing on the other.

Return air
The air conveyed from an air-conditioned space back to the central plant for processing and recirculation.

Supply air
The conditioned air delivered by an air-conditioning system to the served spaces.

Exhaust air
The air exhausted from an interior space to the outside.

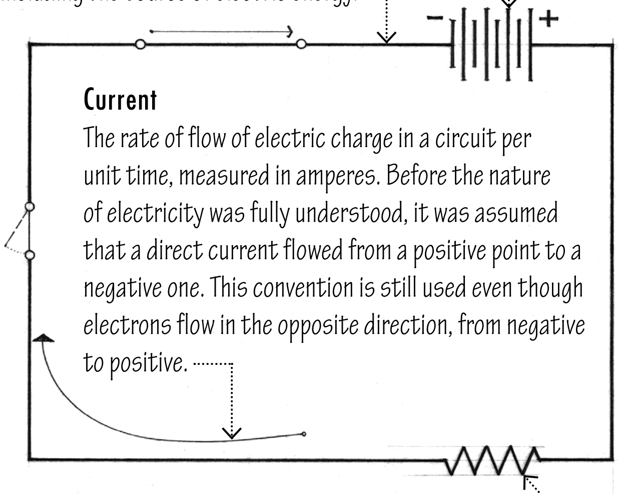
Damper
A movable plate for regulating the draft in an air outlet, air duct, or the throat of a fireplace.

Air-handling unit
An air-conditioning assembly containing the fans, filters, and other components necessary to treat and distribute conditioned air to an entire building or to specific zones within the building.

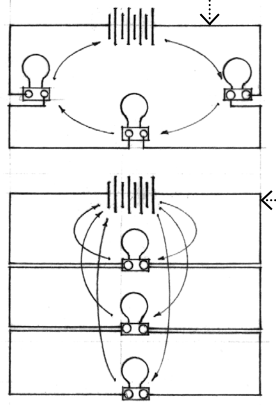
Heat pump
A device that uses a compressible refrigerant to transfer heat from one reservoir to another, with the process being reversible so that it can be used for both heating and cooling a building.

Circuit
The complete path of an electric current, including the source of electric energy.

Battery
A group of two or more cells connected together to produce electric current.



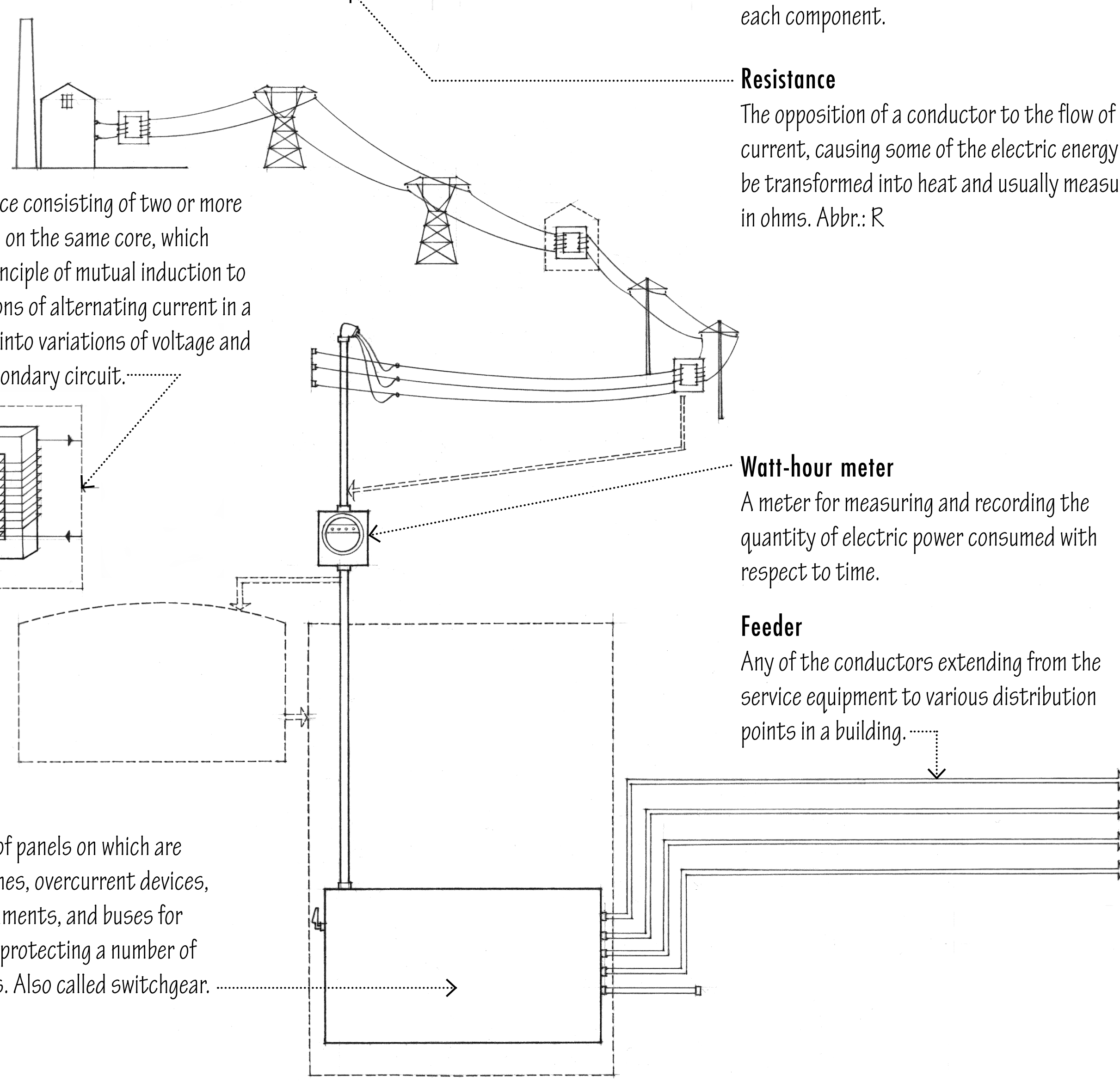
Current
The rate of flow of electric charge in a circuit per unit time, measured in amperes. Before the nature of electricity was fully understood, it was assumed that a direct current flowed from a positive point to a negative one. This convention is still used even though electrons flow in the opposite direction, from negative to positive.



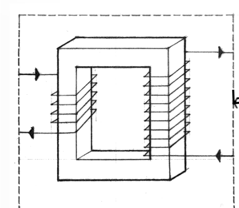
Series
An arrangement of components in an electric circuit in which the same current flows through each component in turn without branching.

Parallel
An arrangement of components in an electric circuit in which all positive terminals are connected to one conductor and all negative terminals are connected to a second conductor, the same voltage being applied to each component.

Resistance
The opposition of a conductor to the flow of current, causing some of the electric energy to be transformed into heat and usually measured in ohms. Abbr.: R



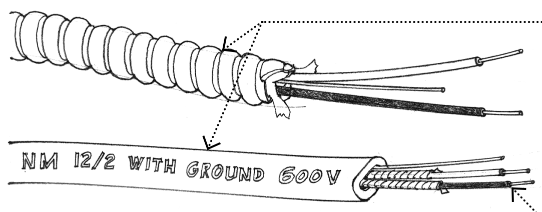
Transformer
An electric device consisting of two or more windings wound on the same core, which employs the principle of mutual induction to convert variations of alternating current in a primary circuit into variations of voltage and current in a secondary circuit.



Watt-hour meter
A meter for measuring and recording the quantity of electric power consumed with respect to time.

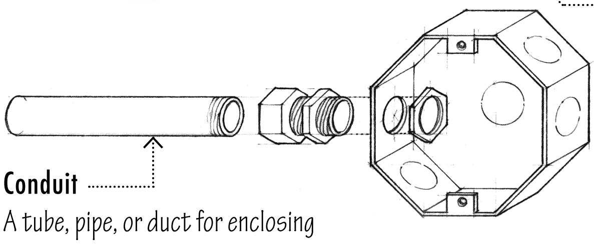
Feeder
Any of the conductors extending from the service equipment to various distribution points in a building.

Switchboard
One or a group of panels on which are mounted switches, overcurrent devices, metering instruments, and buses for controlling and protecting a number of electric circuits. Also called switchgear.

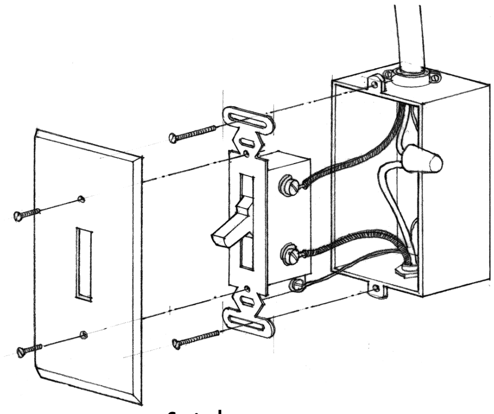


Cable
A single insulated conductor or a bound or sheathed combination of conductors insulated from one another.

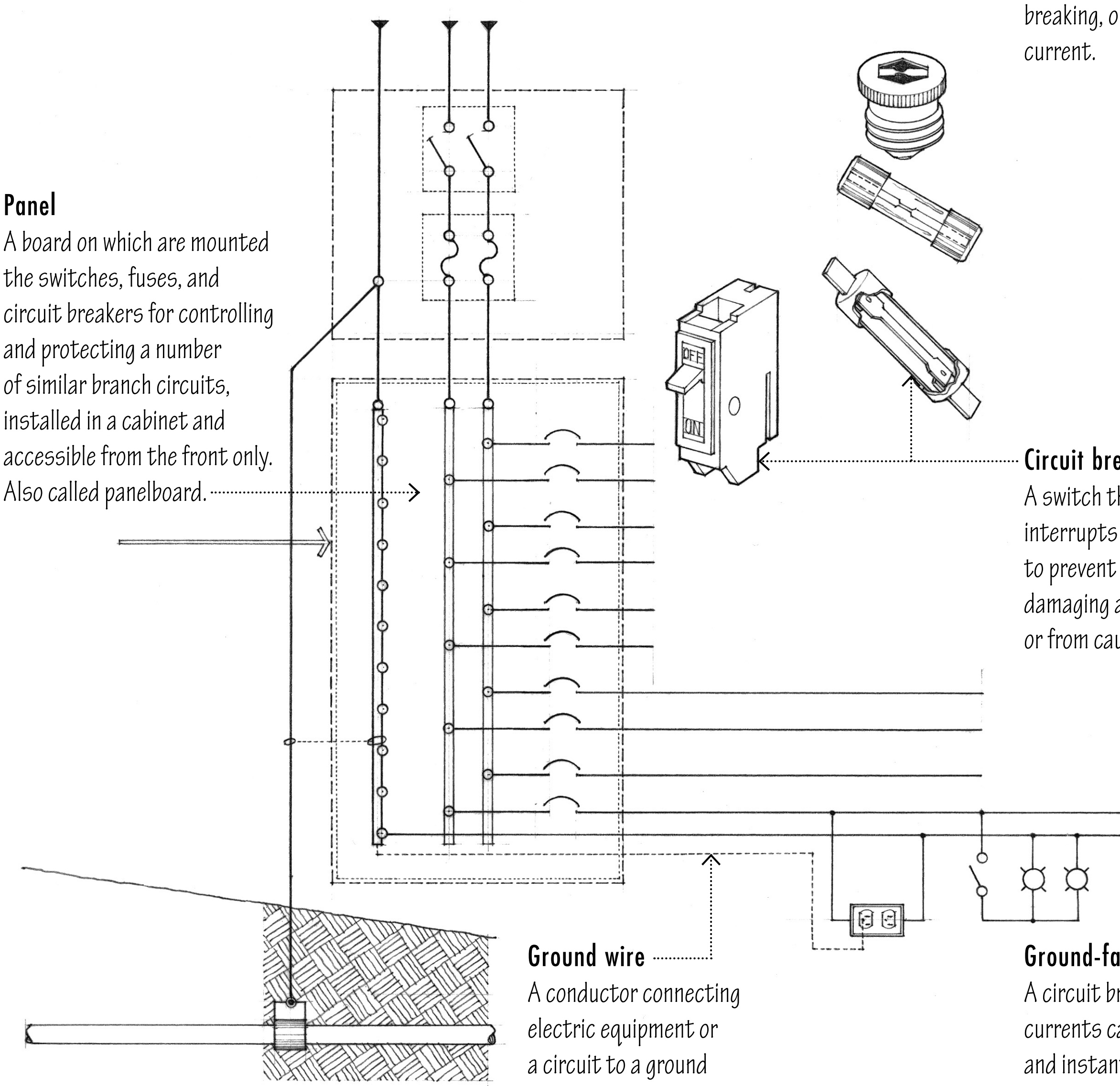
Wire
A pliable metallic strand or a twisted or woven assembly of such strands, often insulated with a dielectric material and used as a conductor of electricity.



Conduit
A tube, pipe, or duct for enclosing and protecting electric wires or cable.

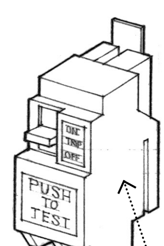


Switch
Any of various devices for making, breaking, or directing an electric current.



Panel
A board on which are mounted the switches, fuses, and circuit breakers for controlling and protecting a number of similar branch circuits, installed in a cabinet and accessible from the front only. Also called panelboard.

Circuit breaker
A switch that automatically interrupts an electric current to prevent excess current from damaging apparatus in the circuit or from causing a fire.



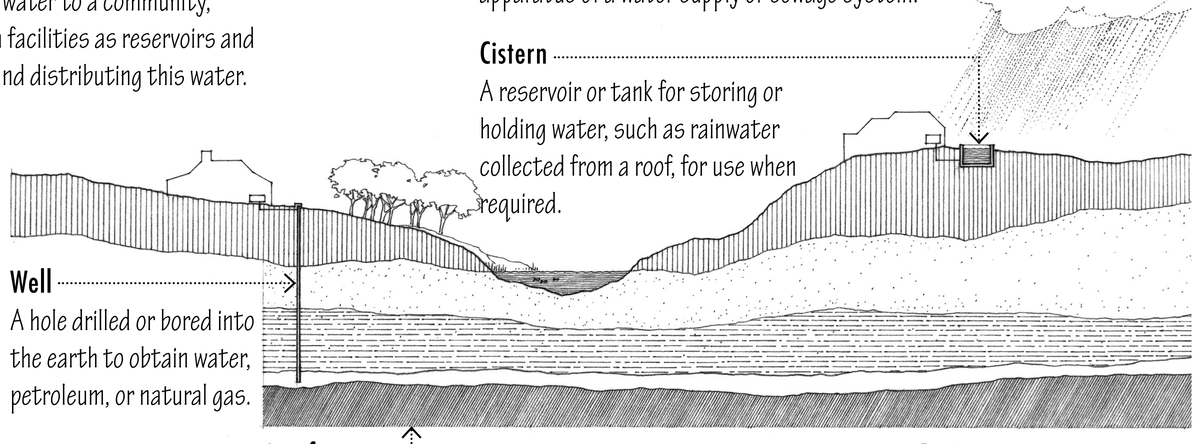
Ground wire
A conductor connecting electric equipment or a circuit to a ground connection. Also called grounding conductor.

Ground-fault interrupter
A circuit breaker that senses currents caused by ground faults and instantaneously shuts off power before damage or injury can occur. Abbr.: gfi

Water supply
The supply of purified water to a community, usually including such facilities as reservoirs and pipelines for storing and distributing this water.

Plumbing
The system of pipes, valves, fixtures, and other apparatus of a water supply or sewage system.

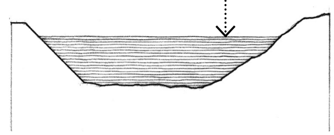
Cistern
A reservoir or tank for storing or holding water, such as rainwater collected from a roof, for use when required.



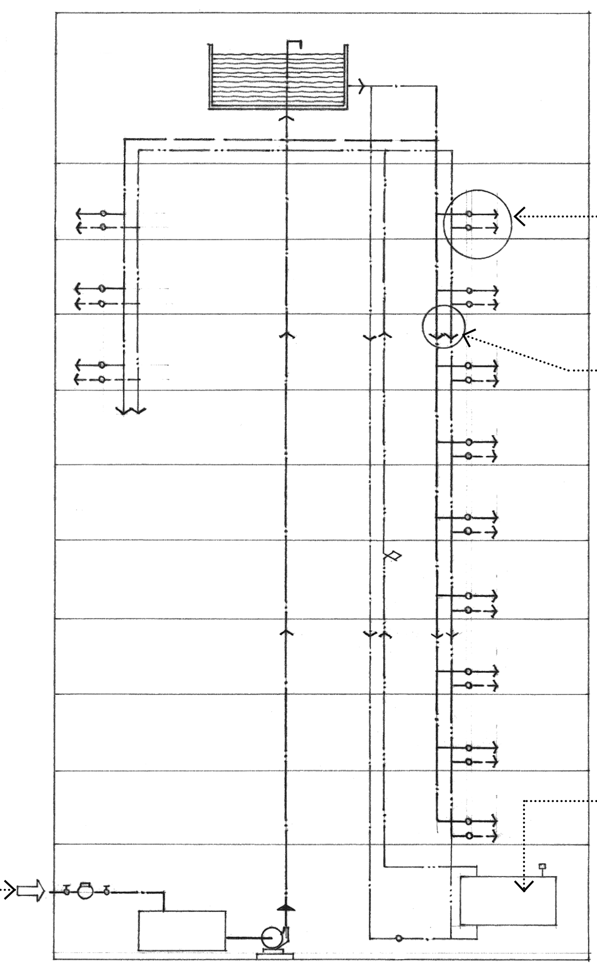
Well
A hole drilled or bored into the earth to obtain water, petroleum, or natural gas.

Potable water
Water fit for human consumption.

Aquifer
A geological formation containing or conducting groundwater, esp. one capable of providing water in usable quantities to springs or wells.



Reservoir
A natural or artificial place where water is collected and stored for use, esp. water for supplying a community, irrigating land, or furnishing power.



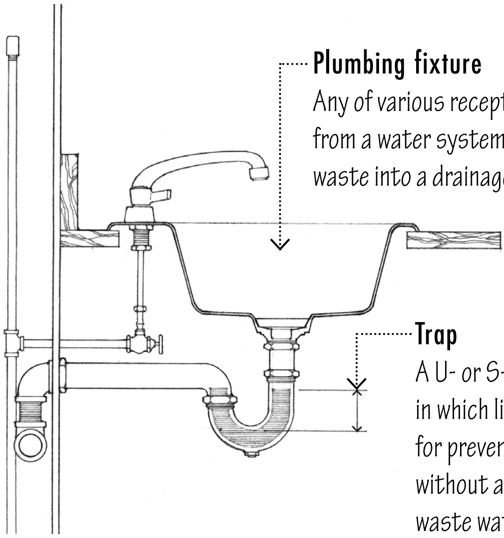
Branch
Any member of a piping system other than a main, riser, or stack.

Riser
A vertical pipe, conduit, or duct in a utility system.

Pipe
A hollow cylinder of metal or plastic used for the conveyance of water, steam, gas, or other fluid material.

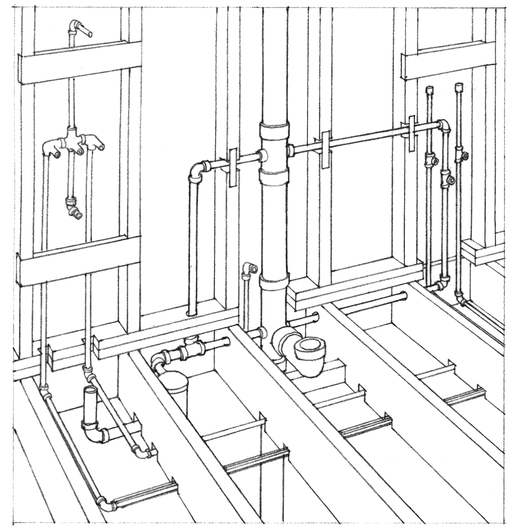
Water heater
An electric or gas appliance for heating water to a temperature between 120°F and 140°F (50°C and 60°C) and storing it for use.

Main
A principal pipe, conduit, or duct in a utility system.

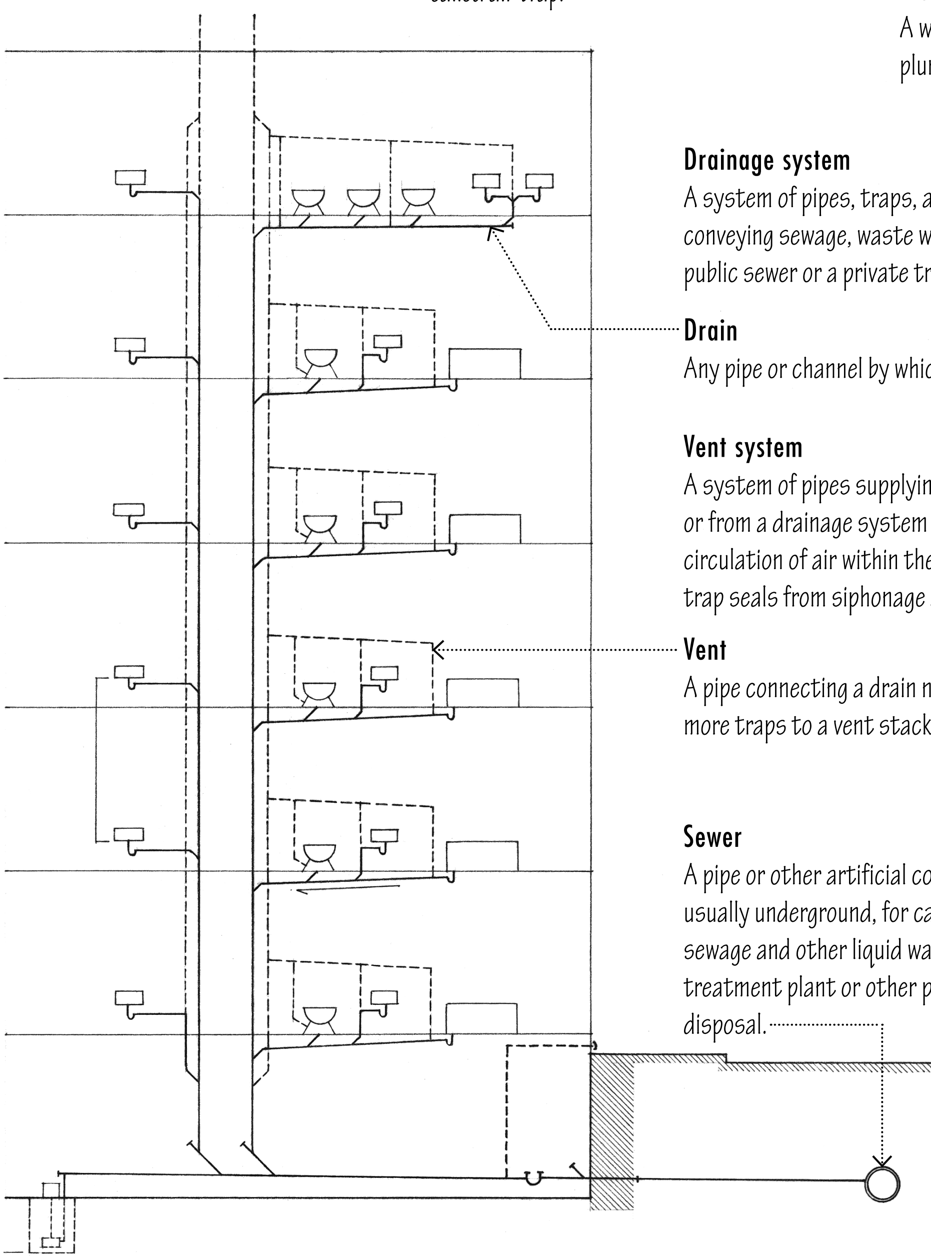


Plumbing fixture
Any of various receptacles for receiving water from a water system and discharging the liquid waste into a drainage system.

Trap
A U- or S-shaped section of drainpipe in which liquid remains and forms a seal for preventing the passage of sewer gas without affecting the normal flow of waste water or sewage through it. Also called air trap.



Plumbing wall
A wall or partition containing vertical space for a plumbing stack. Also called stack partition.



Drainage system
A system of pipes, traps, and other apparatus for conveying sewage, waste water, or rainwater to a public sewer or a private treatment facility.

Drain
Any pipe or channel by which a liquid is drawn off.

Vent system
A system of pipes supplying a flow of air to or from a drainage system or providing a circulation of air within the system to protect trap seals from siphonage and back pressure.

Vent
A pipe connecting a drain near one or more traps to a vent stack or stack vent.

Sewer
A pipe or other artificial conduit, usually underground, for carrying off sewage and other liquid waste to a treatment plant or other point of disposal.

Septic tank
A covered watertight tank for receiving the discharge from a building sewer, separating out the solid organic matter, which is decomposed and purified by anaerobic bacteria, and allowing the clarified liquid to discharge for final disposal.

Structure

Arch
A curved structure for spanning an opening, designed to support a vertical load primarily by axial compression.

Masonry arch
An arch constructed of individual stone or brick voussoirs.

Voussoir
Any of the wedge-shaped units in a masonry arch or vault, having side cuts converging at one of the arch centers.

Keystone
The wedge-shaped, often embellished voussoir at the crown of an arch, serving to lock the other voussoirs in place.

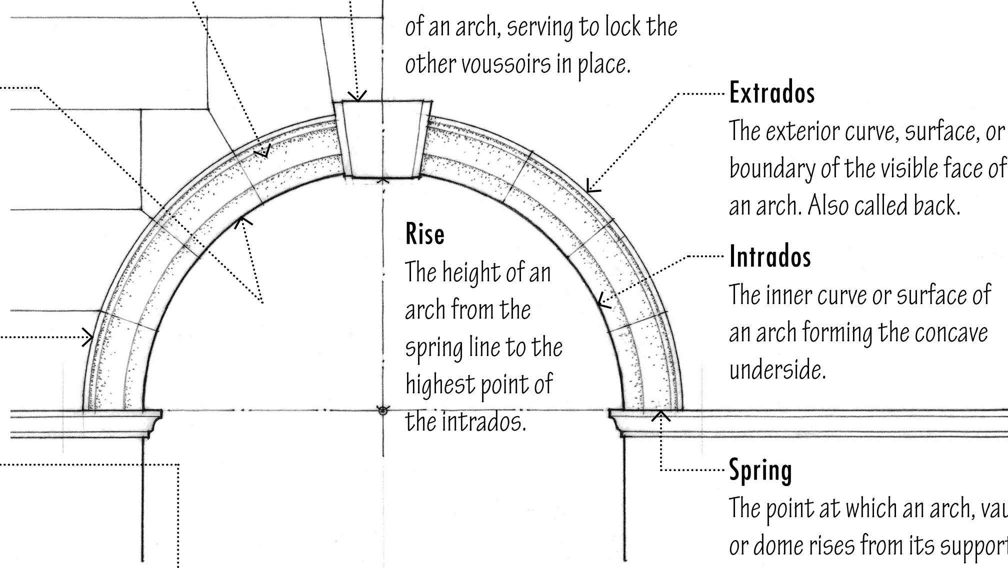
Soffit
The underside of an architectural element, as that of an arch, beam, cornice, or staircase.

Extrados
The exterior curve, surface, or boundary of the visible face of an arch. Also called back.

Rise
The height of an arch from the spring line to the highest point of the intrados.

Springer
The first voussoir resting on the impost of an arch.

Intrados
The inner curve or surface of an arch forming the concave underside.



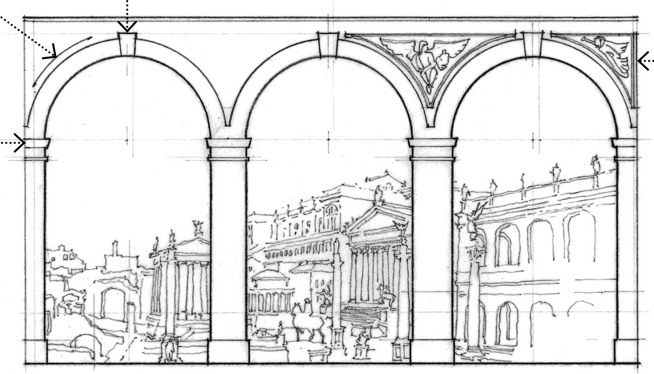
Crown
The highest part or point of a convex construction, such as an arch, vault, or roadway.

Spring
The point at which an arch, vault, or dome rises from its support. Also, springing.

Haunch
Either side of an arch curving down from the crown to the impost.

Spandrel
The triangular-shaped, sometimes ornamented area between the extrados of two adjoining arches, or between the left or right extrados of an arch and the rectangular framework surrounding it.

Impost
The uppermost part of an abutment, often in the form of a block, capital, or molding, from which an arch springs.

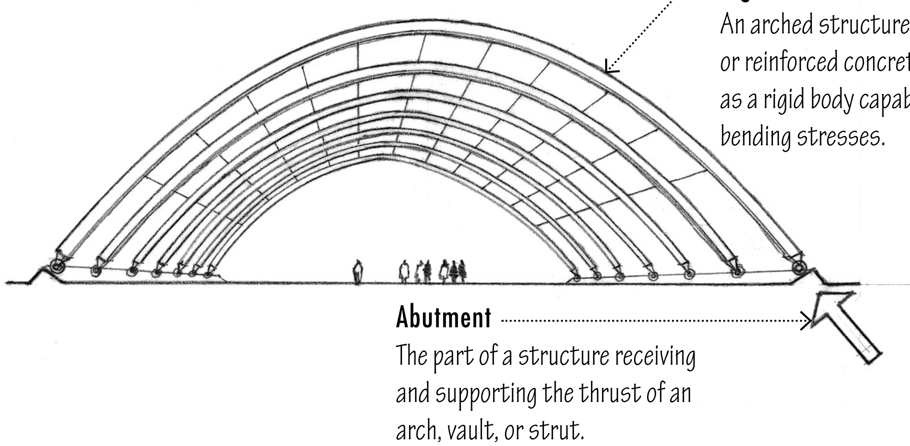


Fixed arch
A fixed frame structure having an arched form.

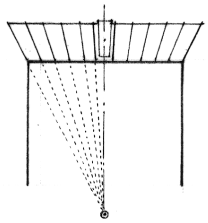
Rigid arch
An arched structure of timber, steel, or reinforced concrete, constructed as a rigid body capable of carrying bending stresses.

Two-hinged arch
A two-hinged frame structure having an arched form.

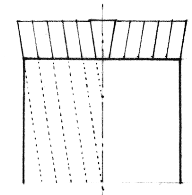
Three-hinged arch
A three-hinged frame structure having an arched form. See frame structure.



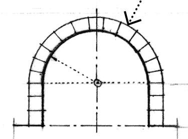
Abutment
The part of a structure receiving and supporting the thrust of an arch, vault, or strut.



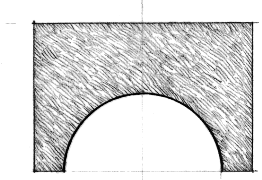
Flat arch
An arch having a horizontal intrados with voussoirs radiating from a center below, often built with a slight camber to allow for settling. Also called jack arch.



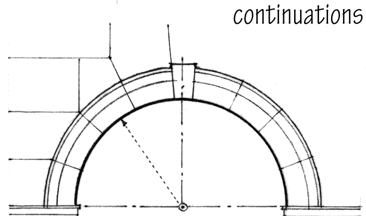
French arch
A flat arch having voussoirs inclined to the same angle on each side of the center.



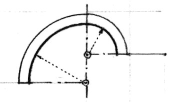
Stilted arch
An arch resting on imposts treated as downward continuations of the archivolt.



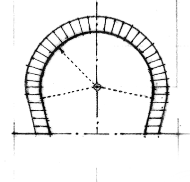
Round arch
An arch having a continuously curved intrados, esp. a semicircular one.



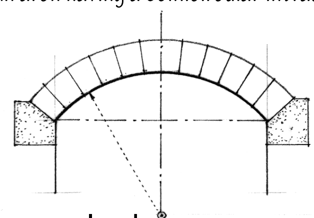
Roman arch
An arch having a semicircular intrados.



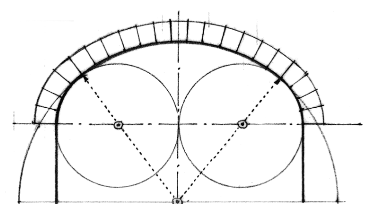
Rampant arch
An arch having one impost higher than the other.



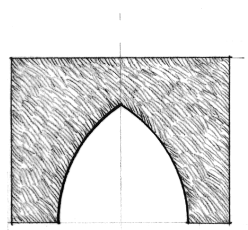
Horseshoe arch
An arch having an intrados that widens above the spring line before narrowing to a rounded crown. Also called Moorish arch.



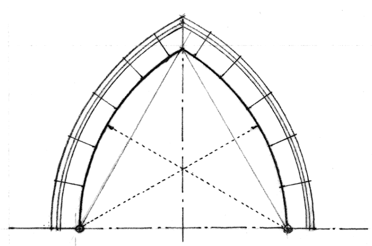
Segmental arch
An arch struck from one or more centers below the spring line.



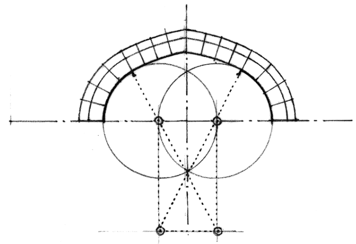
Basket-handle arch
A three-centered arch having a crown with a radius much greater than that of the outer pair of curves. Also called anse de panier.



Pointed arch
An arch having a pointed crown.



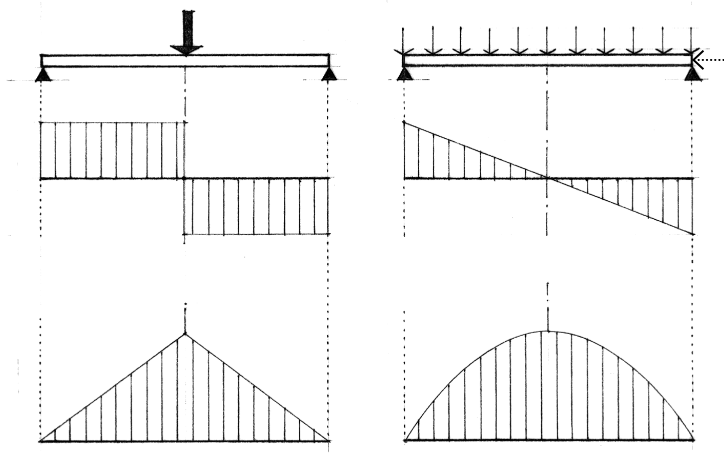
Gothic arch
A pointed arch, esp. one having two centers and equal radii.



Tudor arch
A four-centered arch having an inner pair of curves with a radius much greater than that of the outer pair.

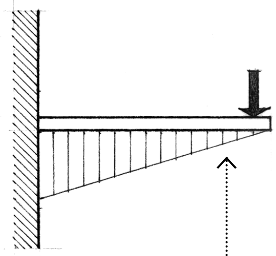
Beam

A rigid structural member designed to carry and transfer transverse loads across space to supporting elements.



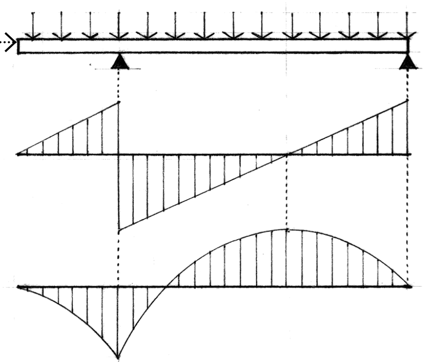
Simple beam

A beam resting on simple supports at both ends, which are free to rotate and have no moment resistance. As with any statically determinate structure, the values of all reactions, shears, and moments for a simple beam are independent of its cross-sectional shape and material.



Overhanging beam

A simple beam extending beyond one its supports. The overhang reduces the positive moment at midspan while developing a negative moment at the base of the cantilever over the support. Assuming a uniformly distributed load, the projection for which the moment over the support is equal and opposite to the moment at midspan is approximately 3/8 of the span.



Cantilever beam

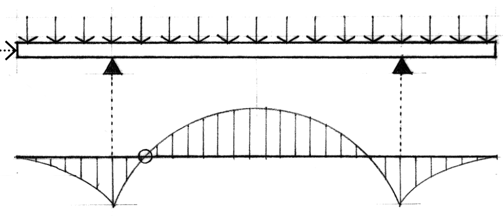
A projecting beam supported at only one fixed end.

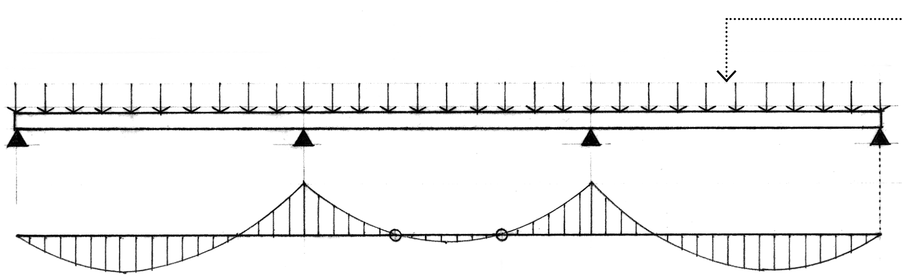
Cantilever

A beam or other rigid structural member extending beyond a fulcrum and supported by a balancing member or a downward force behind the fulcrum.

Double overhanging beam

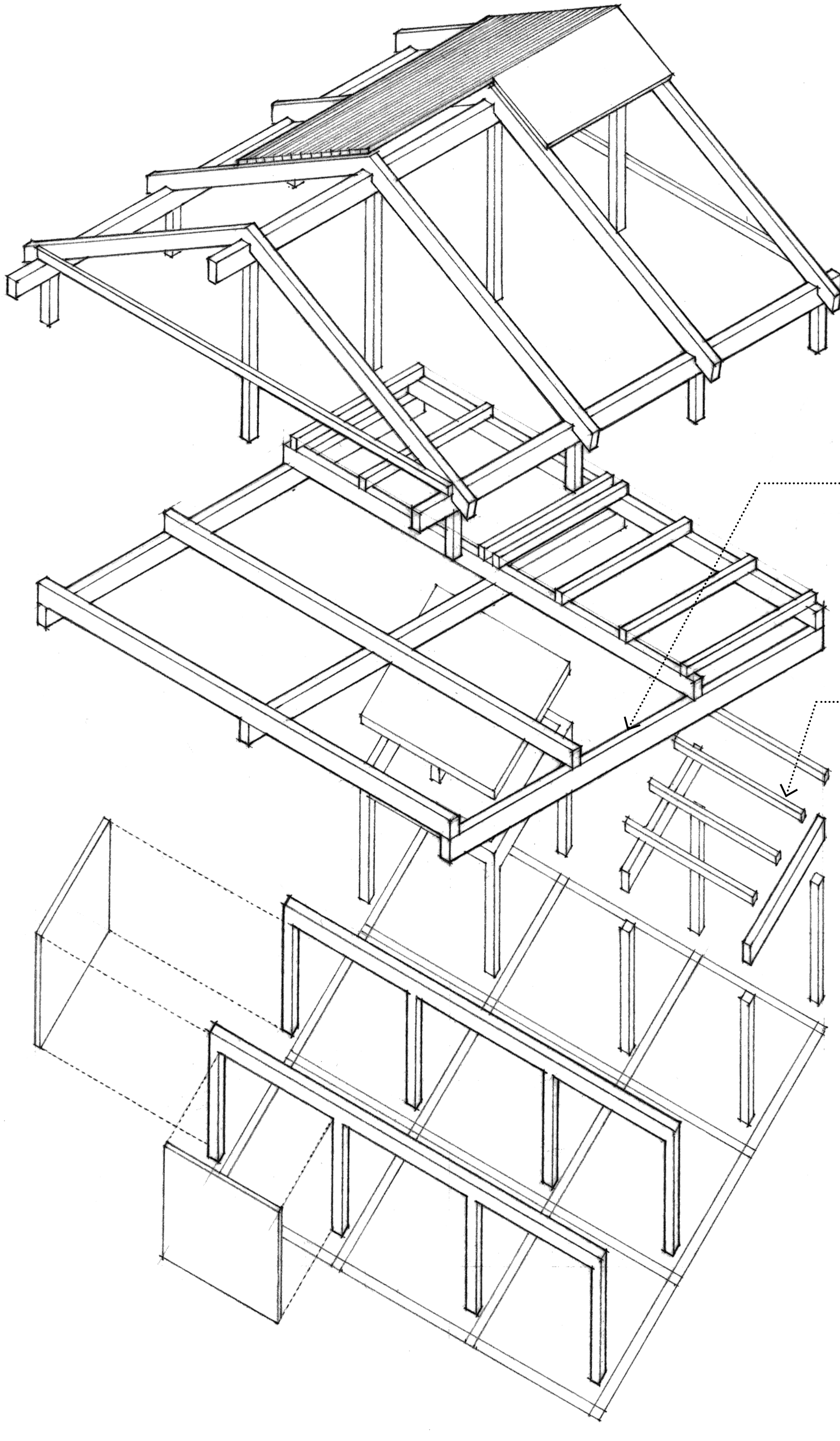
A simple beam extending beyond both of its supports. Assuming a uniformly distributed load, the projections for which the moments over the supports are equal and opposite to the moment at midspan are approximately 1/3 of the span.





Continuous beam

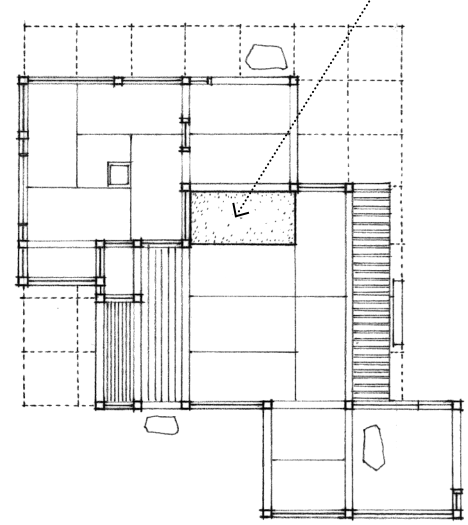
A beam extending over more than two supports in order to develop greater rigidity and smaller moments than a series of simple beams having similar spans and loading. Both fixed-end and continuous beams are indeterminate structures for which the values of all reactions, shears, and moments are dependent not only on span and loading but also on cross-sectional shape and material.



Girder
A large principal beam designed to support concentrated loads at isolated points along its length.

Joist
Any of a series of small, repetitive parallel beams for supporting floors, ceilings, or flat roofs.

Module
A unit of measurement used for standardizing the dimensions of building materials or regulating the proportions of an architectural composition.



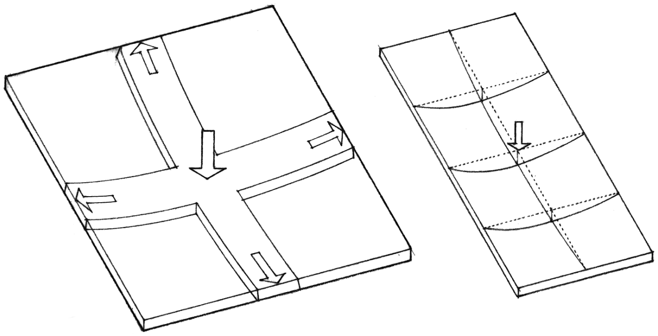
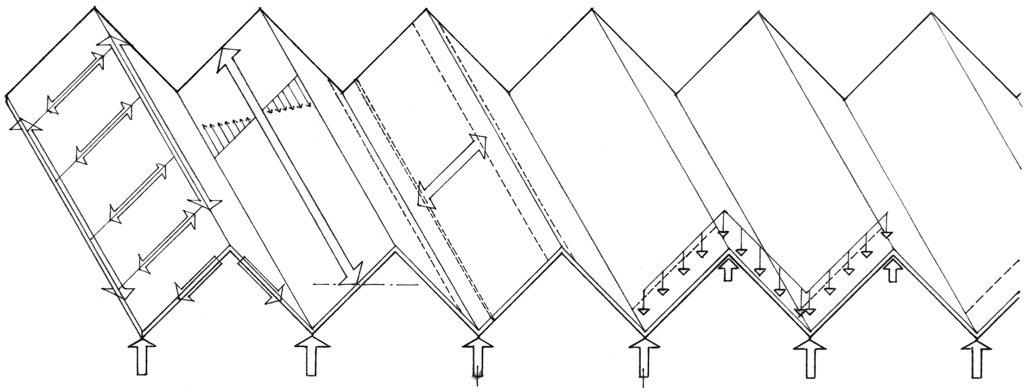
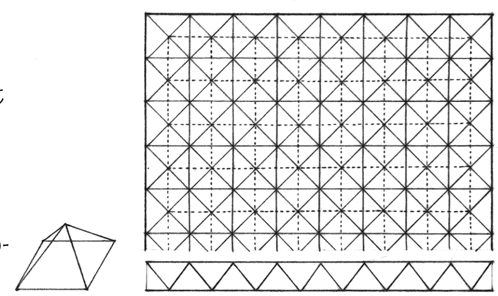


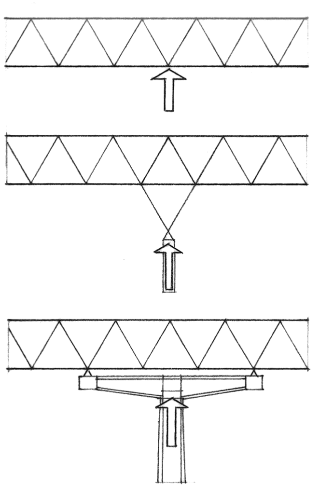
Plate
A rigid, planar, usually monolithic structure that disperses applied loads in a multidirectional pattern, with the loads generally following the shortest and stiffest routes to the supports.



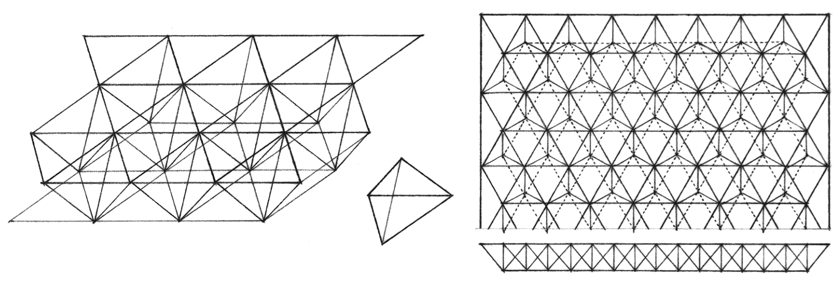
Folded plate
A plate structure composed of thin, deep elements joined rigidly along their boundaries and forming sharp angles to brace each other against lateral buckling.

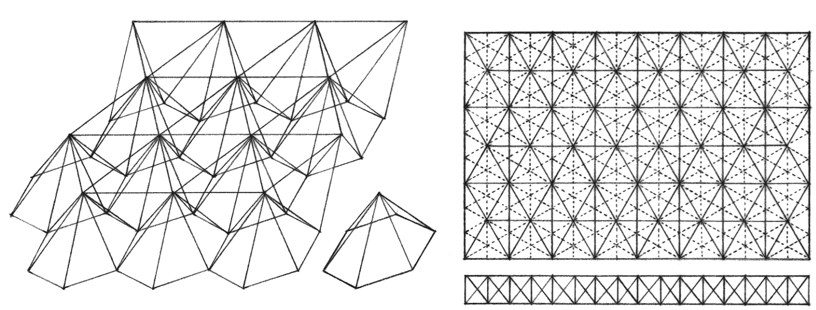
Space frame
A three-dimensional structural frame based on the rigidity of the triangle and composed of linear elements subject only to axial tension or compression. The simplest spatial unit of a space frame is a tetrahedron having four joints and six structural members. As with plate structures, the supporting bay for a space frame should be square or nearly square to ensure that it acts as a two-way structure. Also called space truss.





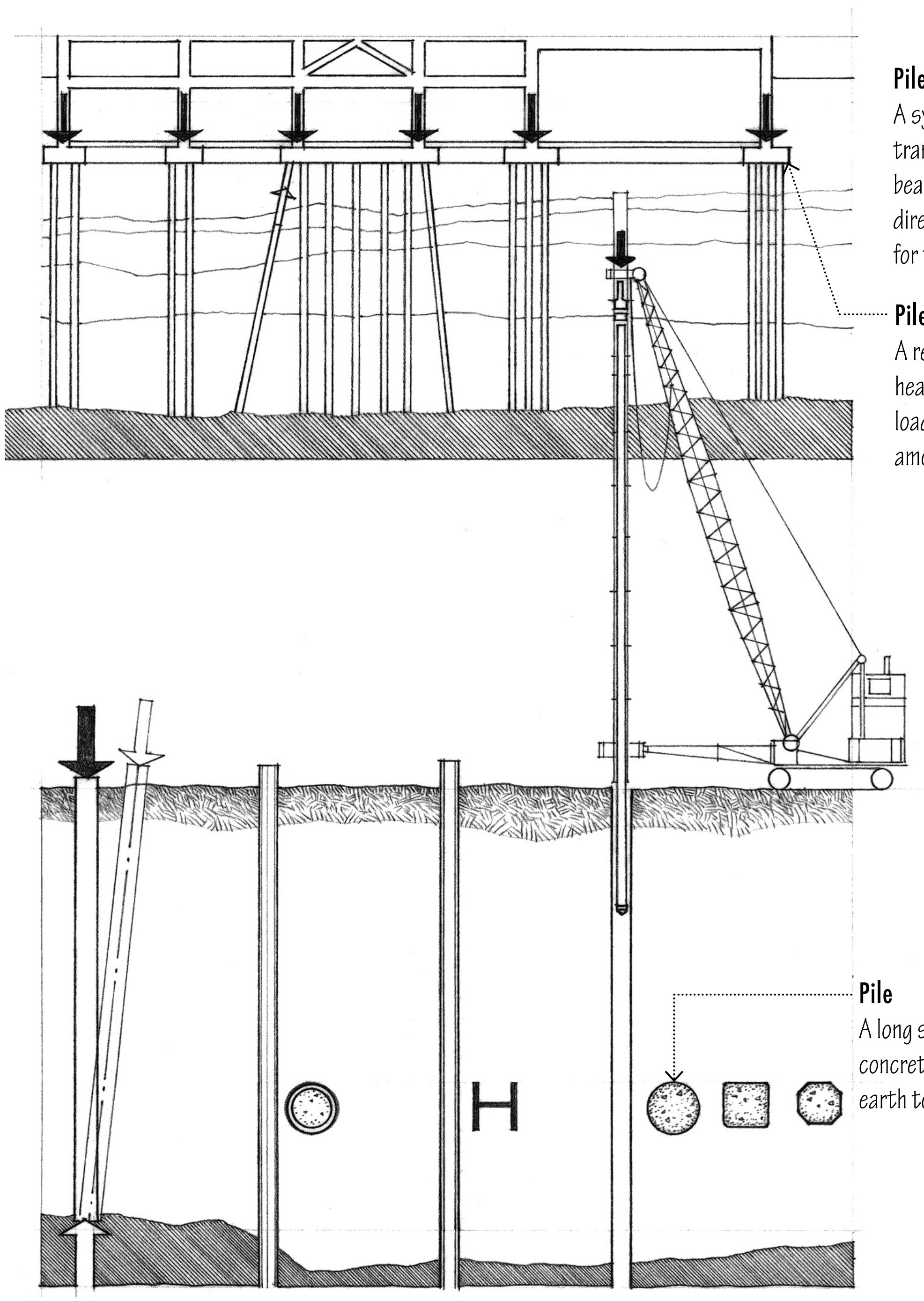
Increasing the bearing area of the supports increases the number of members into which shear is transferred and reduces the forces in the members.





Foundation

Deep foundation
A foundation system that extends down through unsuitable soil to transfer building loads to a more appropriate bearing stratum well below the superstructure.



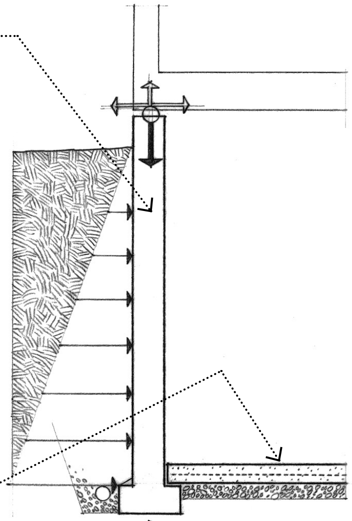
Pile foundation
A system of piles, pile caps, and tie beams for transferring building loads down to a suitable bearing stratum, used esp. when the soil mass directly below the construction is not suitable for the direct bearing of footings.

Pile cap
A reinforced concrete slab or mat joining the heads of a cluster of piles to distribute the load from a column or grade beam equally among the piles.

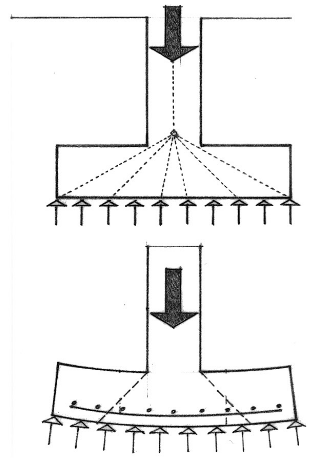
Pile
A long slender column of wood, steel, or reinforced concrete, driven or hammered vertically into the earth to form part of a foundation system.

Foundation wall
A wall occurring below the floor nearest grade, designed to support and anchor the superstructure.

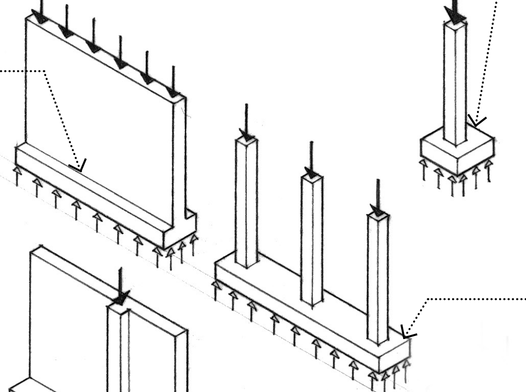
Ground slab
A concrete slab placed over a dense or compacted base and supported directly by the ground, usually reinforced with welded wire fabric or a grid of reinforcing bars to control any cracking caused by drying shrinkage or thermal stresses. Separate or integral footings are required for heavy or concentrated loads. Over problem soils, the slab must be designed as a mat or raft foundation. Also called slab on grade.



Spread footing
A concrete footing extended laterally to distribute the foundation load over a wide enough area that the allowable bearing capacity of the supporting soil is not exceeded.



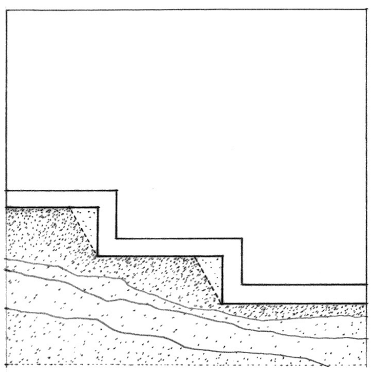
Strip footing
The continuous spread footing of a foundation wall.



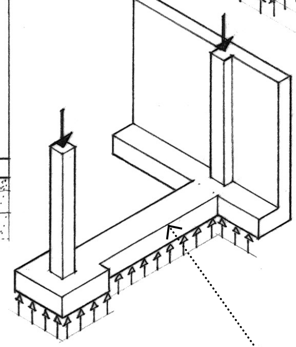
Isolated footing
A single spread footing supporting a freestanding column or pier.

Plinth
The usually square slab beneath the base of a column, pier, or pedestal.

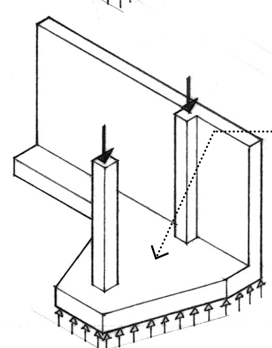
Continuous footing
A reinforced concrete footing extended to support a row of columns.



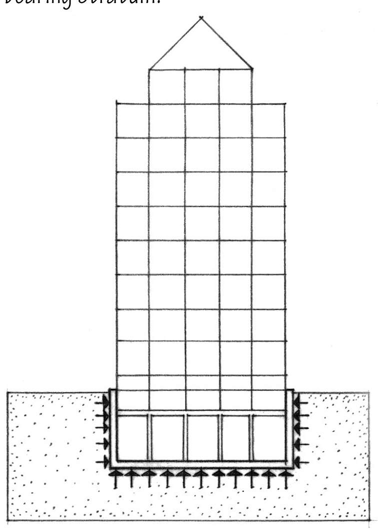
Stepped footing
A continuous or strip footing that changes levels in stages to accommodate a sloping site or bearing stratum.

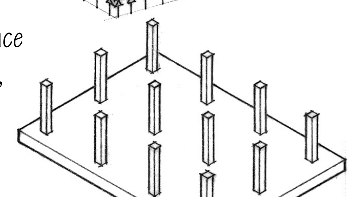


Cantilever footing
A reinforced concrete footing connected by a tie beam to another footing in order to balance an asymmetrically imposed load, as at the perimeter of a building site. Also called strap footing.



Combined footing
A reinforced concrete footing for a perimeter column or foundation wall extended to support an interior column load.





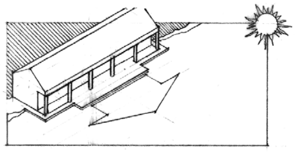
Floating foundation
A foundation used in yielding soil, having for its footing a raft placed deep enough that the weight of the excavated soil is equal to or greater than the weight of the construction supported.

Mat
A thick, slablike footing of reinforced concrete supporting a number of columns or an entire building.

Building Site

Orientation
The position of a building on a site in relation to true north, to points on the compass, to a specific place or site feature, or to local conditions of sunlight, wind, and drainage.

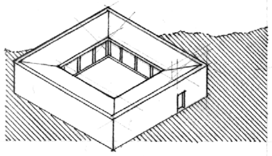
Front
To face in a specific direction or look out upon.

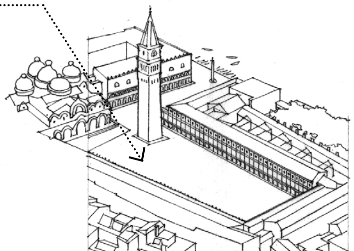


Folly
A whimsical or extravagant structure built to serve as a conversation piece, lend interest to a view, or commemorate a person or event, found esp. in eighteenth-century England.

Pavilion
A small, often ornamental building in a garden.

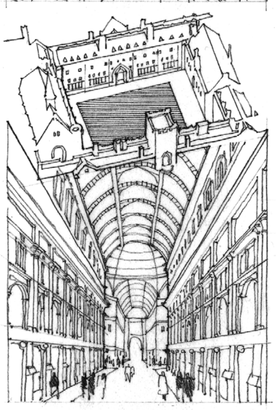
Piazza
An open square or public place in a city or town, esp. in Italy.



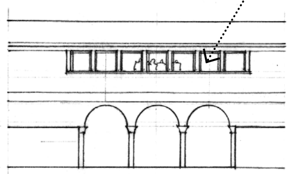


Gazebo
A freestanding roofed structure, usually open on the sides, affording shade and rest in a garden or park.

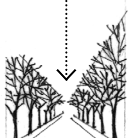
Promenade
An area used for a stroll or walk, esp. in a public place, as for pleasure or display.



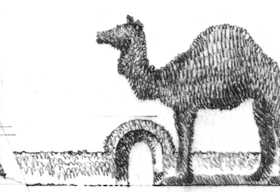
Belvedere
A building, or architectural feature of a building, designed and situated to look out upon a pleasing scene.

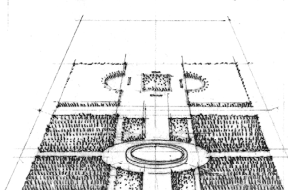


Allée
French term for a broad walk planted with trees.



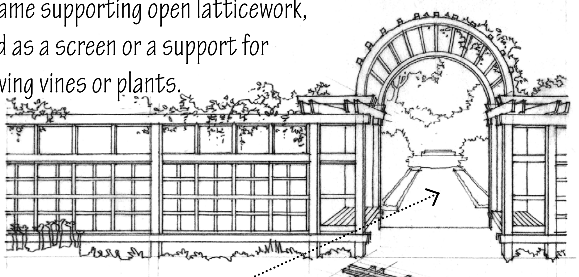
Topiary
The work or art of clipping or trimming into ornamental and fantastic shapes.



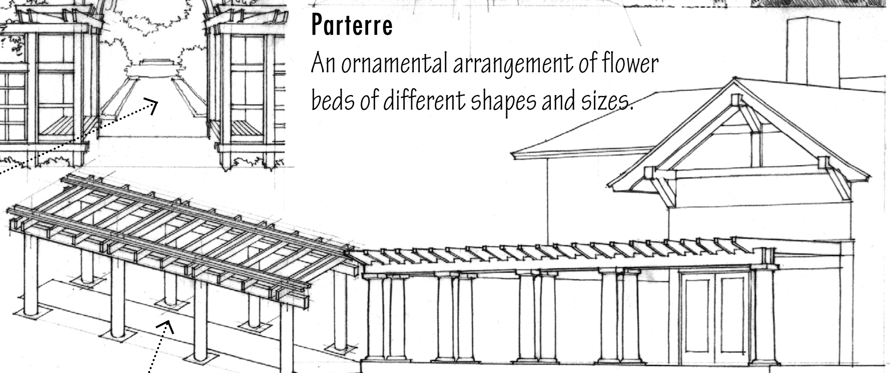


Trellis
A frame supporting open latticework, used as a screen or a support for growing vines or plants.

Parterre
An ornamental arrangement of flower beds of different shapes and sizes.



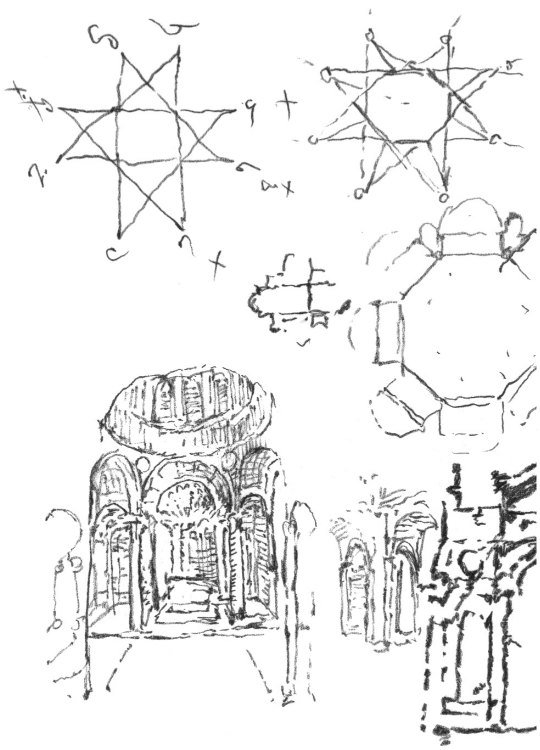
Arbor
A shelter of shrubs and branches or of latticework intertwined with climbing vines and flowers.



Pergola
A structure of parallel colonnades supporting an open roof of beams and crossing rafters or trelliswork, over which climbing plants are trained to grow.

8 The Design Process:

Tools and Techniques for Generating Ideas



Fragment of studies by Leonardo da Vinci

What Is the Design Process?

The design process is not a method. Method implies that results can be predicted to a certain degree of accuracy. Instead, the design process is an exploration. It is a series of actions by which the architect is able to generate ideas from the things that he or she makes. Often the ideas that are generated are completely unexpected; new possibilities can be seen once old ones are tested.

Design process is something where rudimentary ideas can be gradually developed over into complex pieces of architecture. Every idea can be tested multiple times through different media. Each time a new version is made, it is edited according to the successes and failures of previous versions. For this to work, the architect must rely on a wide array skills and techniques along with a creative impulse. Every architect's process is different; often each project demands a different process to be undertaken. However, in general, the design process is nonlinear in that similar ideas are revisited at various stages of the process, and it is synthetic in that it combines a variety of making techniques, analysis, and research.

Architects will often move back and forth between drawing, sketching, and modeling as they seek new ideas and new information. They will combine research of a site, a place, and precedents with observations of existing conditions. As all of these sources are continuously combined in various ways, the architectural idea can emerge, be explored, and ultimately realized as a building.

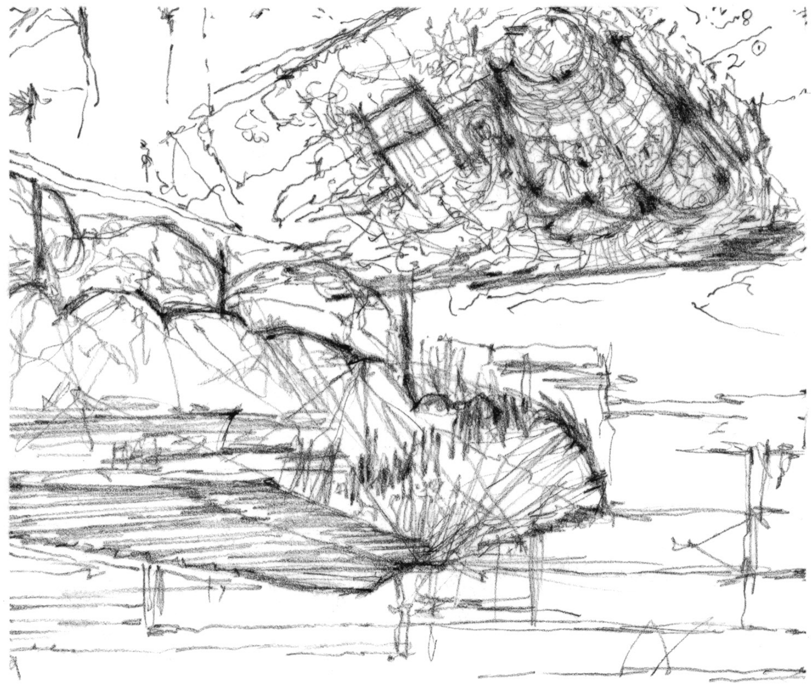
This chapter provides an overview of just some of the techniques used by an architect in the design process. They present a means to produce, examine, critique, and develop the architectural concept. It is important to remember that rather than prescribed methodology, the ideas discussed here are strategies to consider as one is making and thinking.

Speculative Drawing

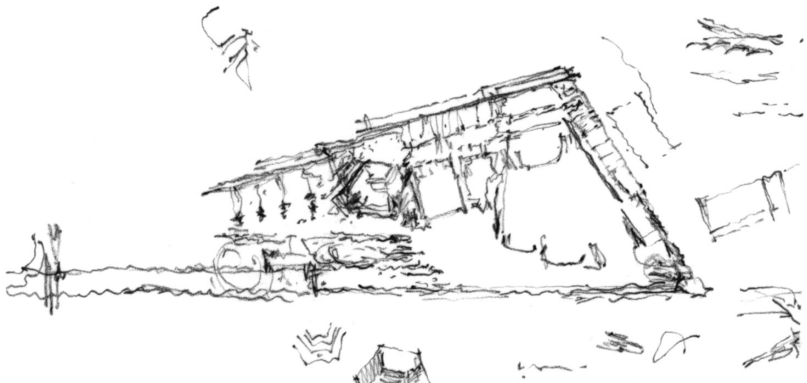
To speculate is to engage in thought or reflection. In design, we speculate about the future. As we think about what might be possible in the future, drawing gives material existence to our conceptions so that they can be seen, assessed, and acted upon. The drawing out of these ideas, whether executed quickly or slowly, roughly or carefully, is necessarily speculative in nature. We can never determine beforehand precisely what the final outcome will be. The developing image on paper gradually takes on a life of its own and guides the exploration of a concept as it travels between mind and paper and back again.

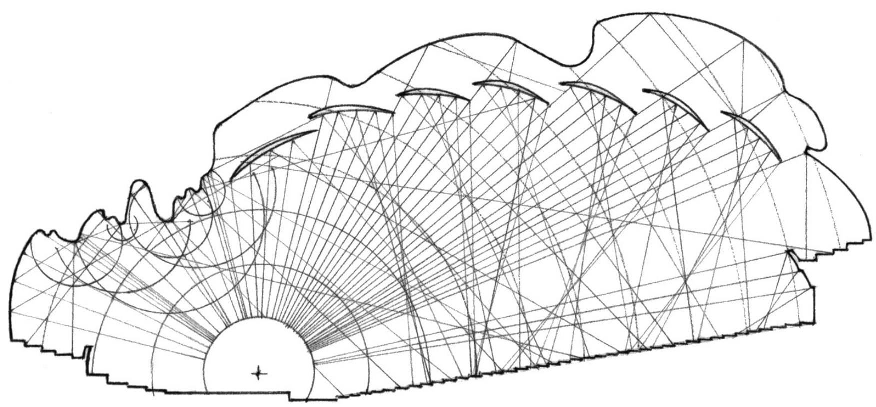
In the generative and developmental stages of the design process, drawing is distinctly speculative in nature. Thoughts come to mind as we view a drawing in progress, which can alter our perceptions and suggest possibilities not yet conceived. The emerging image on paper allows us to explore avenues that could not be foreseen before the drawing was started but that generate ideas along the way. Once executed, each drawing depicts a separate reality that can be seen, evaluated, and refined or transformed. Even if eventually discarded, each drawing will have stimulated the mind's eye and set in motion the formation of further conceptions.

Therefore, speculative drawing is different in spirit and purpose from the definitive presentation drawings we use to accurately represent and communicate a fully formed design to others. While the technique and degree of finish of exploratory drawings may vary with the nature of the problem and one's individual way of working, the mode of drawing is always open-ended, informal, and personal. While not intended for public display, these drawings can provide valuable insights into an individual's creative process.



Facsimile of design studies for the Concert and Convention Hall, Helsinki, 1967–1971, Alvar Aalto.





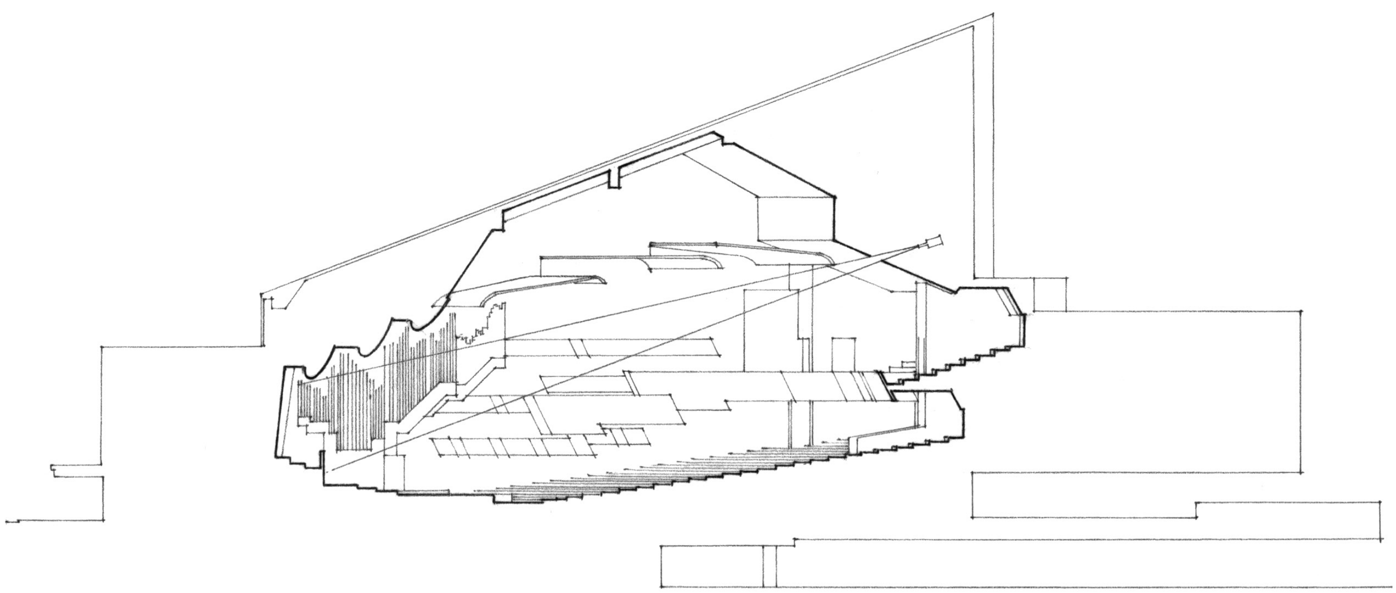
Concert and Convention Hall, Helsinki, 1967–1971, Alvar Aalto. Acoustic study of the concert hall.

The Creative Process

Speculative drawing is a creative process. The imagination triggers a concept that is seen as a flashing and dimensionless image in the mind's eye. The drawing of that idea, however, does not arrive full-blown and complete. Images rarely exist in the mind fully formed down to the last detail, waiting only to be transferred to a sheet of paper. They develop over time and undergo a number of transformations as we probe the idea each represents and search for congruence between the image in the mind's eye and the one we are drawing.

If we draw blindly, as if following a recipe, we limit ourselves only to preconceived images and miss opportunities for discovery along the way. While a prior image is necessary to initiate a drawing, it can be a hindrance if we do not see that the evolving image is something we can interact with and modify as we draw. If we can accept this exploratory nature of drawing, we open up the design process to opportunity, inspiration, and invention.

Facsimile of a sketch of the unrealized baldachin for the Cathedral of Mallorca, Antonio Gaudi.



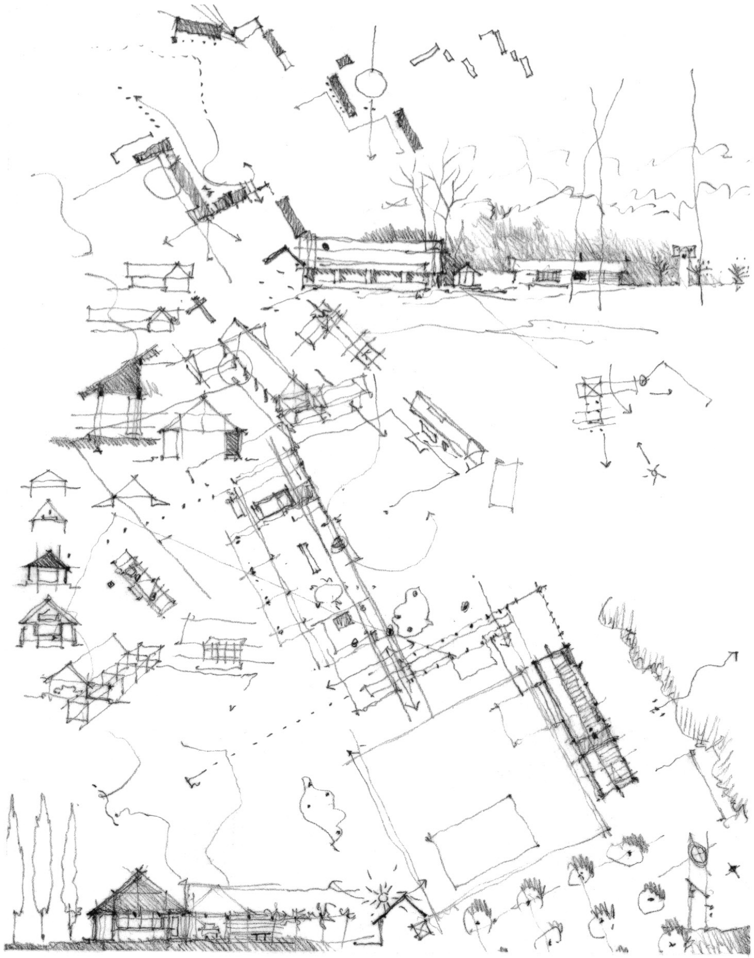
Concert and Convention Hall, Helsinki, 1967–1971, Alvar Aalto. Section showing the interior of the concert hall.

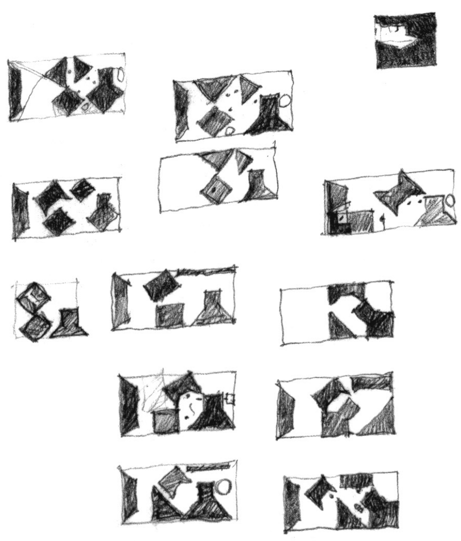
Thinking on Paper

Visual thought is the essential complement to verbal thought in cultivating insights, seeing possibilities, and making discoveries. We also think in visual terms when we draw. Drawing enables the mind to work in graphic form without consciously intending to produce a work of art. Just as thought can be put into words, ideas can take on a visual form to be studied, analyzed, and refined.

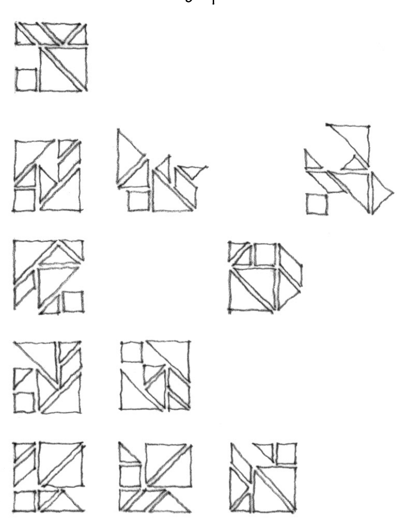
In thinking about a design problem, ideas naturally come to mind. Such ideas are often not verbal. The creative process inevitably involves visualizing a potential outcome in the form of images that are not clearly or completely crystallized. It is difficult to hold such ideas in memory long enough to clarify, assess, and develop them. In order to commit an idea to paper quickly enough to keep up with our thoughts, we rely on diagrams and thumbnail sketches. These generative drawings lead the way in formulating possibilities.

The smaller a drawing, the broader the concept it forms. We begin with small sketches since they allow a range of possibilities to be explored. Sometimes a solution will emerge quickly. More often, however, many drawings are required to reveal the best choice or direction to pursue. They encourage us to look at alternative strategies in a fluent and flexible manner and not close on a solution too fast. Being speculative in nature and, thus, subject to interpretation, they help us avoid the inhibiting nature of a more careful drawing, which often leads to premature closure of the design process.





Facsimile of plan compositions for the Fort Wayne Fine Arts Center, Fort Wayne, Indiana, 1961–1964, Louis Kahn



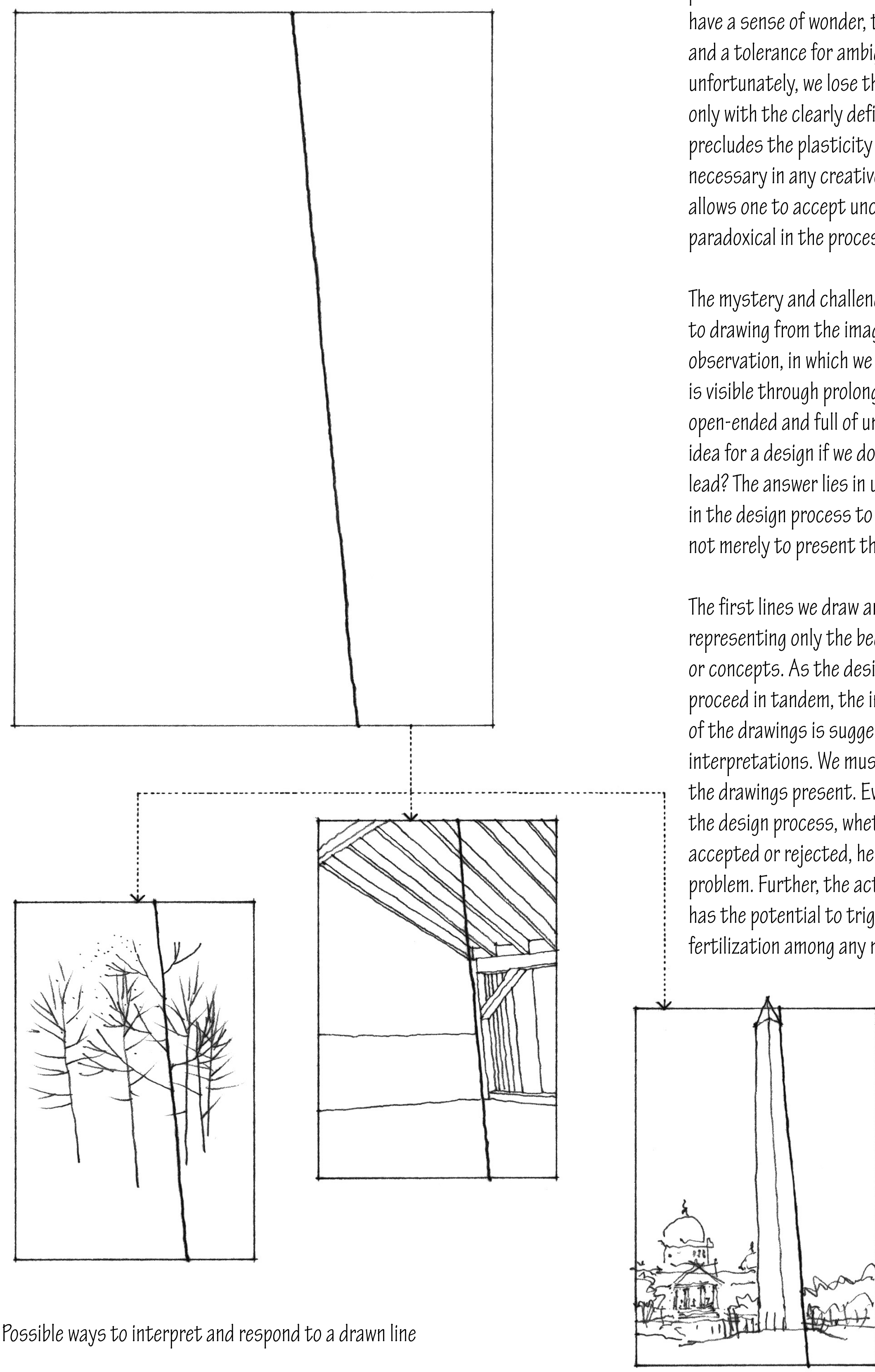
Tangram compositions

Tolerating Ambiguity

The design process leads into uncharted territory. To pursue what we do not already know, it is necessary to have a sense of wonder, the patience to suspend judgment, and a tolerance for ambiguity. In accepting ambiguity, unfortunately, we lose the comfort of familiarity. Dealing only with the clearly defined and the familiar, however, precludes the plasticity and adaptability of thought necessary in any creative endeavor. Tolerating ambiguity allows one to accept uncertainty, disorder, and the paradoxical in the process of ordering one's thoughts.

The mystery and challenge of ambiguity applies as well to drawing from the imagination. Unlike drawing from observation, in which we are able to represent a subject that is visible through prolonged viewing, speculative drawing is open-ended and full of uncertainty. How can we draw out an idea for a design if we do not know where the process will lead? The answer lies in understanding that we use drawing in the design process to stimulate and extend our thinking, not merely to present the results of the process.

The first lines we draw are necessarily tentative, representing only the beginning of a search for ideas or concepts. As the design and drawing processes proceed in tandem, the incomplete and ambiguous state of the drawings is suggestive and subject to multiple interpretations. We must be open to the possibilities the drawings present. Every drawing we produce during the design process, whether the idea it represents is accepted or rejected, helps us gain further insight into a problem. Further, the act of drawing an idea out on paper has the potential to trigger new ideas and enhance cross-fertilization among any number of previous ideas.



Possible ways to interpret and respond to a drawn line

Relying on Intuition

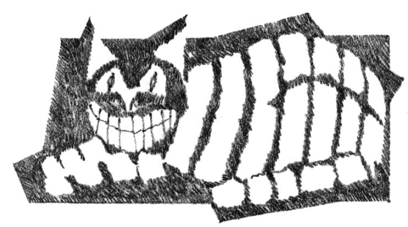
In the search for possibilities and to outline choices, we rely on intuition as a guide. Intuition, however, is based on informed experience. We cannot draw out what is not already within each one of us. Drawing requires understanding of what it is we are drawing. For example, it is difficult to convincingly draw a form whose structure we do not understand. Yet the act of trying to draw it out can lead the way to understanding and guide the intuitive search for ideas.

The first lines we draw are the most difficult. We often fear even beginning until an idea is fully formed in our head. Faced with a blank sheet of paper, what does one draw first? We may start with specific aspects of a particular form or setting, or begin with a more generalized image of a concept or construct. In either case, where we start is not as important as where we end up.

Drawing too carefully in the early stages of the design process can lead to hesitation and disrupt our thinking about the problem. The time and energy spent on the creation of a drawing can inhibit the willingness to explore other possibilities. We should understand that speculative drawing is a trial-and-error process in which the most important step is to set down the first few lines on paper, no matter how tentative they might be. We must trust our intuition if we are to move forward in the drawing process.

"...'How can I design if I do not know what the end result will be like?' is a frequent complaint. 'Why would you need to design if you already knew?' is my response. The need for a prior image is most keenly felt when we do not trust the form as something to work with. There is nothing wrong with having such an image, but it is not a prerequisite and may be a hindrance. When we speak with other people, we need not know what the result of the conversation will be either. We may come out of the conversation with a better sense of the issue; in fact, we may have changed our mind. When we are concerned about 'doing our own thing' and feel we must be on top of the form all the time, we cannot relax and trust the process. Once students find out how one's dialogue with the form will always bear the imprint of one's personality—whether one likes it or not—the complaint is no longer heard."

—John Habraken
The Control of Complexity. Places/Vol. 4, No. 2



"One day Alice came to a fork in the road and saw a Cheshire cat in a tree.
'Which road do I take?' she asked.
His response was a question: 'Where do you want to go?'
'I don't know,' Alice answered. 'Then,' said the cat, 'it doesn't matter.'"

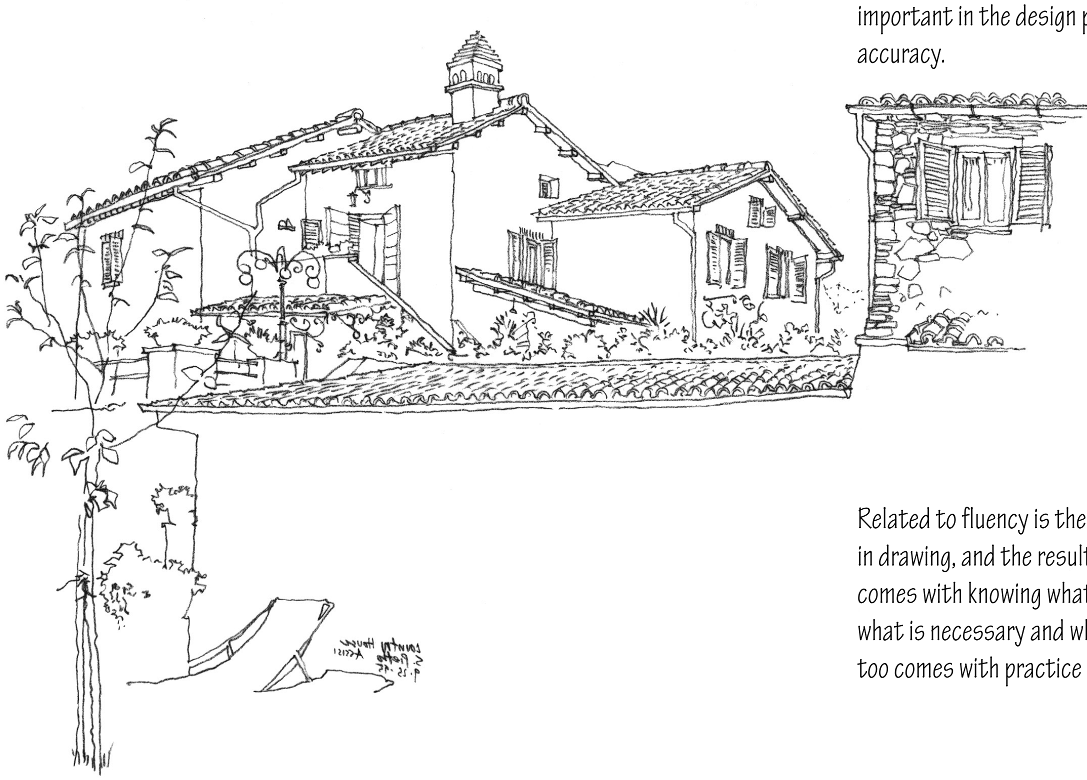
—Lewis Carroll
Alice in Wonderland

Developing Fluency

To be fluent in the creative process is to be able to generate a wide range of possibilities and ideas. To be fluent in the drawing process is to be intuitive when placing pen or pencil to paper, responding with ease and grace to our conceptions. We must be able keep up with our thoughts, which can be fleeting.

Writing our thoughts out is an easy, almost effortless task. To develop this same fluency in drawing, we must practice on a regular basis until putting lines down on paper is an automatic reflex, a natural response to what we are seeing or imagining. While speed may come with pushing ourselves to draw faster, speed without discipline is counterproductive. Before drawing can become an intuitive component of our visual thinking, we must first be able to draw slowly, deliberately, and accurately.

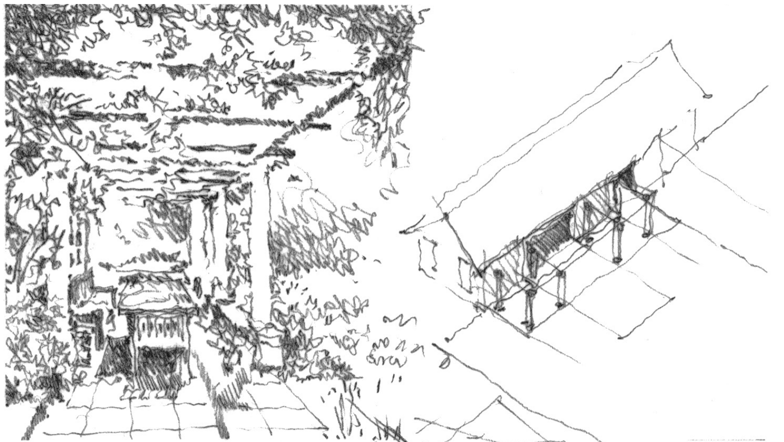
A quick mode of drawing is necessary to capture a brief moment in the flow of ideas, which cannot always be directed or controlled. Fluency in drawing therefore requires a freehand technique, with a minimum of tools. Attention paid to the mechanics of drawing with drafting equipment or to the menu and palette structure of digital software can divert time and energy from the visual thinking process. We should, therefore, draw freehand whenever fluency and flexibility are more important in the design process than precision and accuracy.



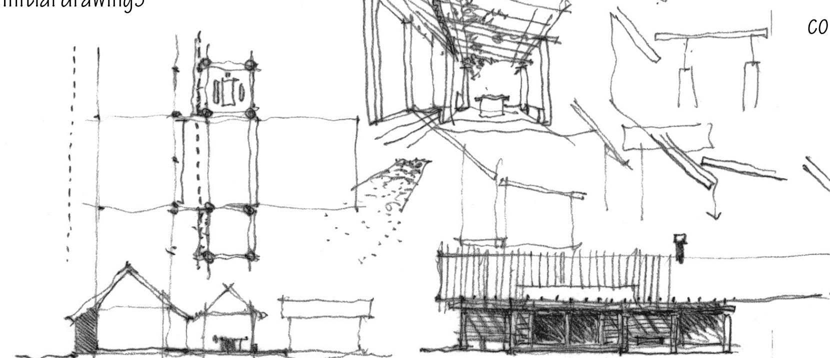
Related to fluency is the idea of efficiency. Efficiency in drawing, and the resulting increase in drawing speed, comes with knowing what to draw and what to omit, what is necessary and what is incidental. This knowledge too comes with practice and experience.

Taking Advantage of Chance

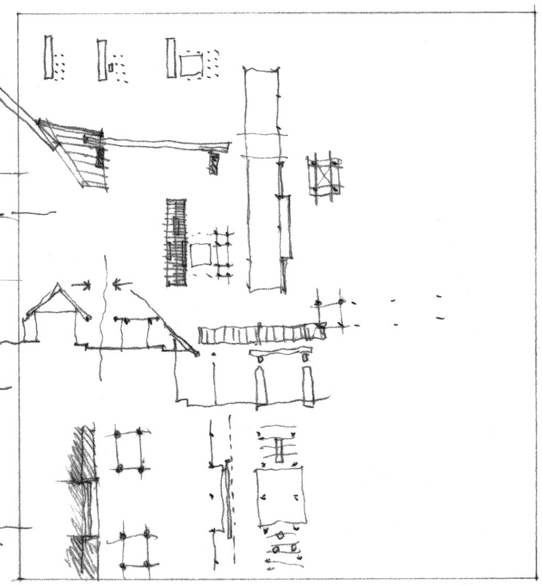
In any creative process, we must be prepared to take advantage of the unexpected. Drawing allows us to explore avenues that could not be foreseen before the process was initiated but that generate ideas along the way. If we remove ourselves from the position of author and view our drawings as an objective observer, they can present possibilities not yet conceived. These are involuntary products of an inner vision. Ideas naturally come to mind when we look at a drawing. As a single visual idea triggers other ideas, one drawing leads to another and another. Even if not serving an immediate purpose, speculative drawings can still be useful for future reference and to stimulate seeing in new ways. And through a series of drawings, we are able to see unexpected relationships, make connections, or recall other patterns.

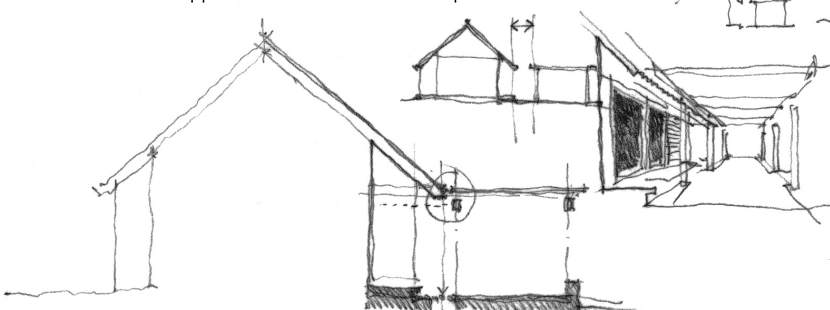


Initial drawings

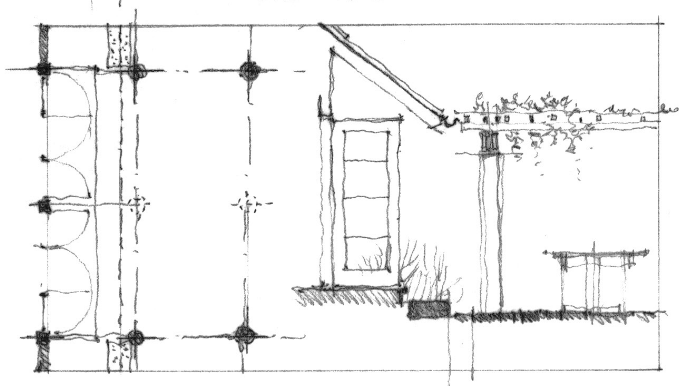


Opportunities arise for development





Alternatives explored

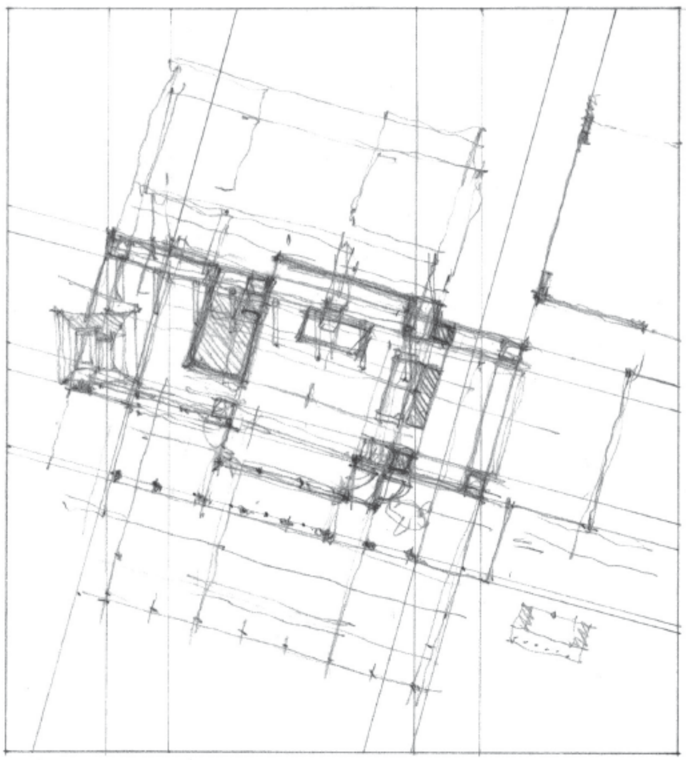


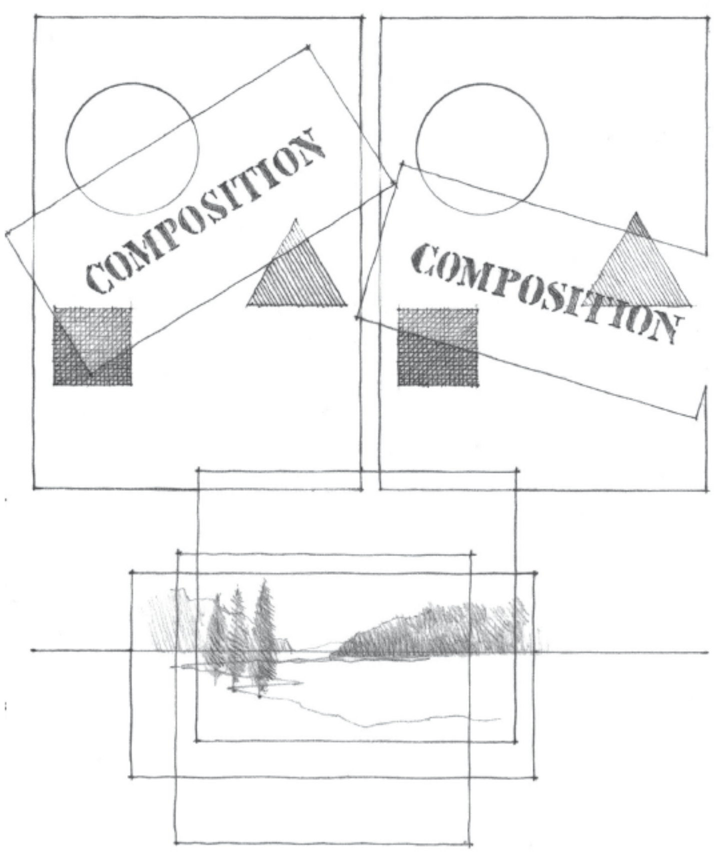
serendipity n. The aptitude for making desirable and unexpected discoveries by accident.

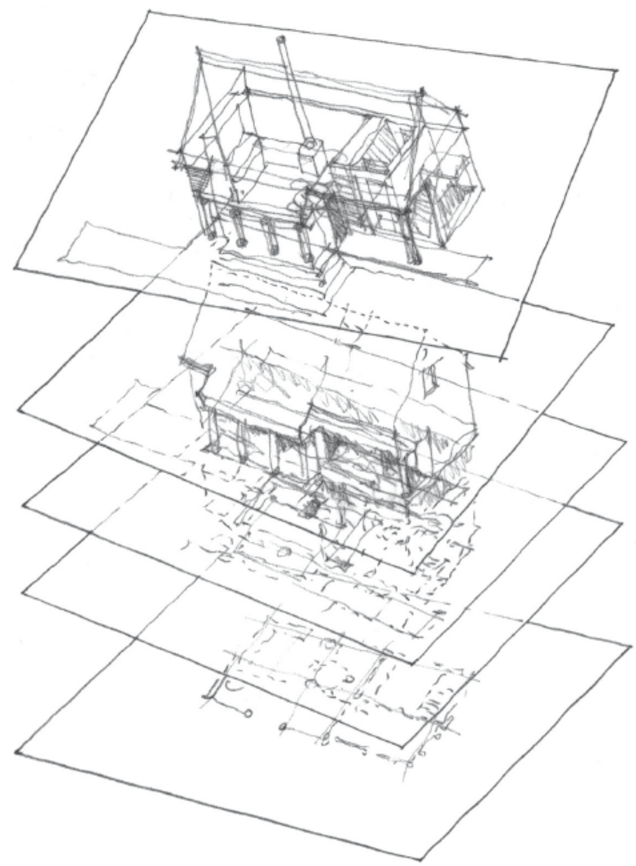
Layering

Layering is a graphic mode for both analysis and synthesis. It allows us to quickly and flexibly see patterns and study relationships. Just as we refine our written thoughts by editing and rewriting drafts, we can build up a drawing in layers on a single sheet of paper. We first draw the foundation or structural lines of the image lightly in an exploratory manner. Then, as we make visual judgments on shape, proportion, and composition, we draw over the emerging image in a number of discrete steps. The process may include both sketchy and detailed work as the mind focuses in on some areas for closer inspection while keeping an eye on the whole.

The revision of a drawing can also occur through the physical layering of transparent sheets. Tracing paper allows us to draw over another drawing, retaining certain elements, and refining others. On separate transparent overlays, we can draw patterns of elements, associated forms and groupings, and relevant relationships. Different layers may consist of separate but related processes. We can study certain areas in greater detail and give greater emphasis to certain aspects or features. We can explore alternatives over common ground.





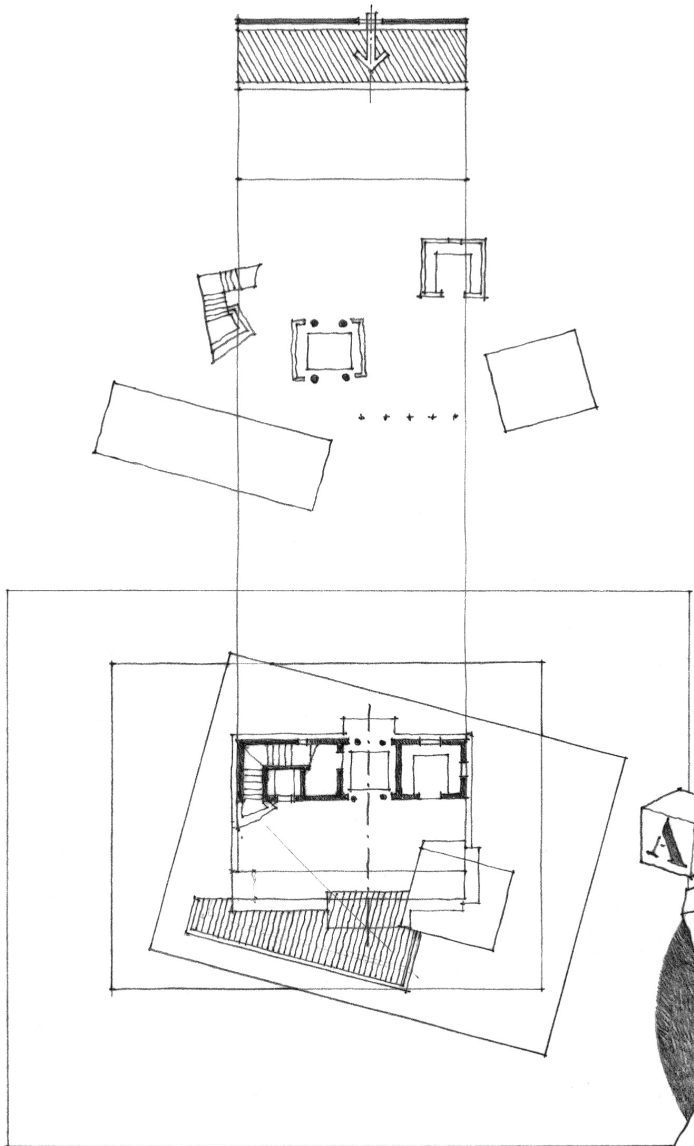


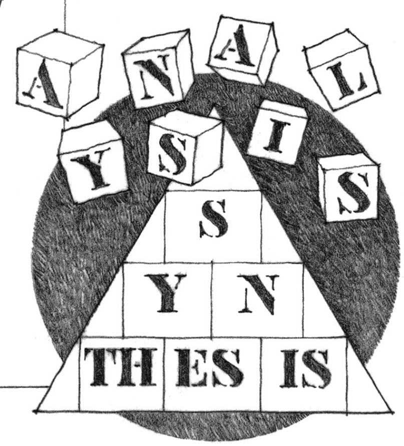
Recombining

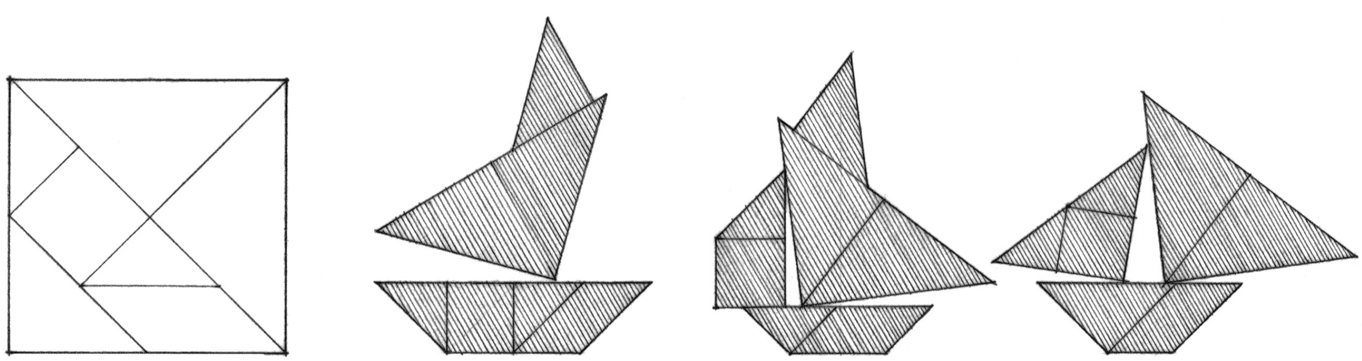
Drawing provides the means by which one can see things that are not possible in reality. As we draw, we can vary the arrangement of information. We can free the information from its normal context so that it can come together in a new way. We can fragment, sort, and group according to similarities and differences. We can alter existing relationships and study the effects of new groupings.

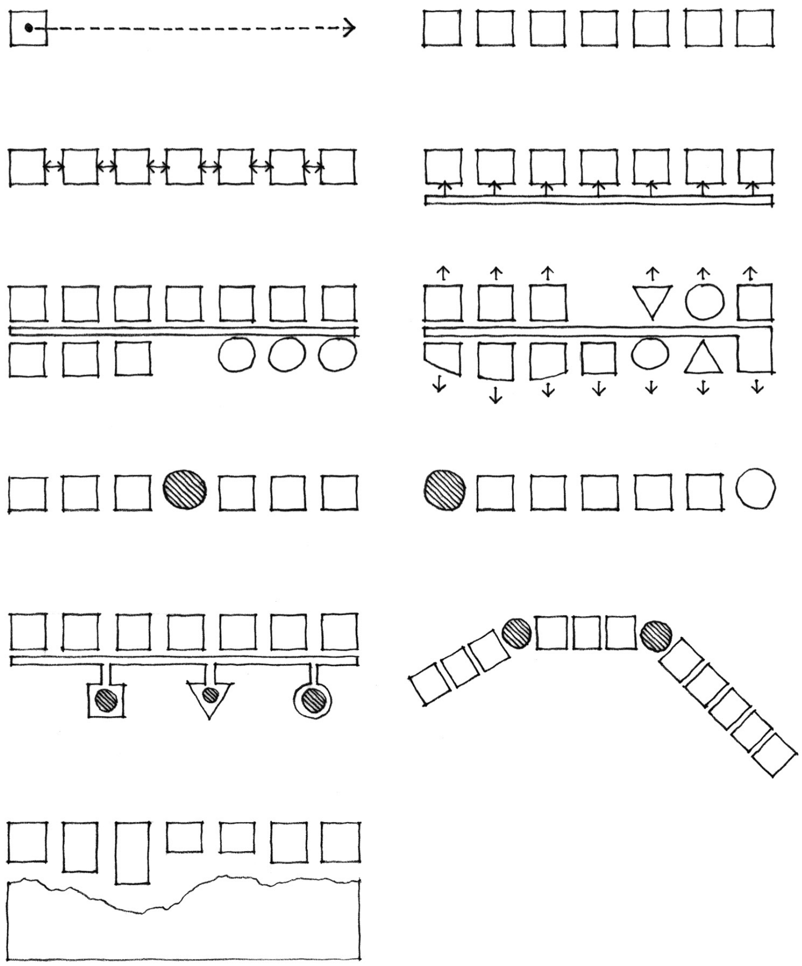
When exploring a series of design possibilities, it can be advantageous to remove, relocate or recombine the elements of a form, space, or composition. This process can be as simple as carving away a part and reattaching it in a different location. It can involve extending one element or form to intersect with another, or superimposing completely different elements or ordering system over each other.

Once recorded on paper, we can spread these alternatives out for comparison, rearrange them, and manipulate them as in a collage. We can evaluate the ideas and develop them further, or we can discard them, bring others back for reconsideration, or incorporate new ideas into the next stages of progress.







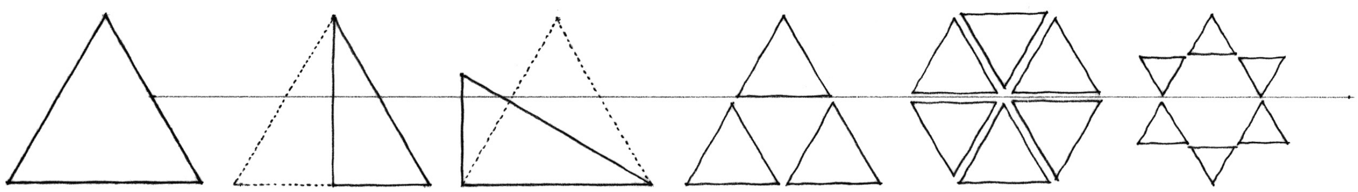


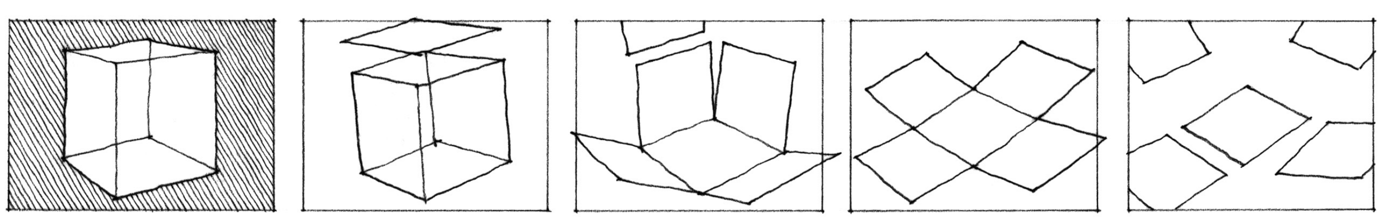
Transforming

Drawing is only a translation of what we are envisioning. As we commit an image to paper, the mind's eye filters out what is interesting or important. The more important points will tend to rise to the surface, while lesser ones will be discarded in the process. As drawings record our thoughts, they then become independent objects for study, elaboration, and the stimulation of new ideas.

Drawing represents ideas in a tangible form so that they can be clarified, assessed, and acted upon. Every drawing undergoes a number of transformations and evolves as we respond to the emerging image. Once drawn, the graphic images have a physical presence that stands apart from the process of their creation. They serve as catalysts that play back into the mind and provoke further study and development of the ideas in our head.

In the process of exploring an idea and pursuing possibilities as they arise, we develop a series of drawings, which we can arrange side by side as alternatives to compare and evaluate. We can combine them in new ways; we can transform them into new ideas. The principle of transformation allows a concept to undergo a series of discrete manipulations and permutations in response to certain directives. In order to force a shift in our thinking, we can transform the familiar to the strange and the strange to the familiar.

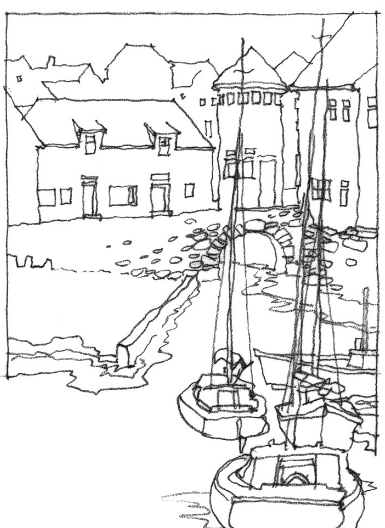


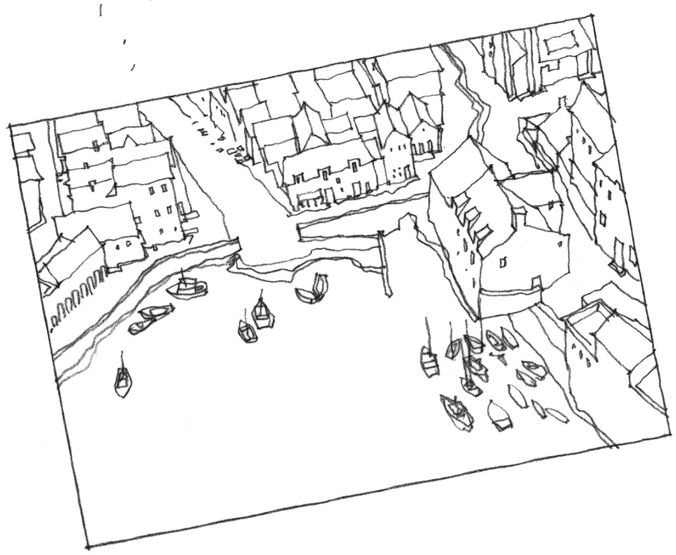


Being Flexible

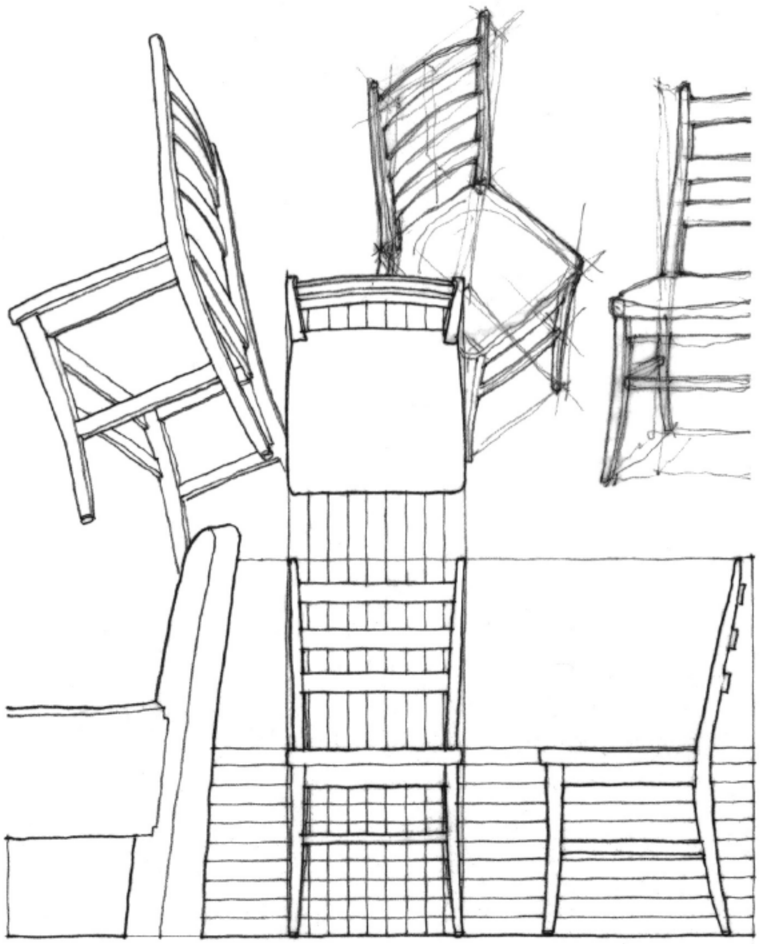
To be flexible is to be able to explore a variety of approaches as new possibilities arise. Flexibility is important because how we draw affects the unconscious direction of our thinking and how our visual thoughts are formed and articulated. If we feel comfortable knowing how to draw only one way, we unnecessarily limit our thinking. To be able to look at a problem in different ways requires being able to draw these various views. We must become familiar and fluent with various drawing media, techniques, and conventions, and view them simply as tools to be selected according to their appropriateness to the task at hand.

A flexible approach to drawing is the beginning of a search that often involves trial and error. The willingness to ask "what if . . .?" can lead to alternatives worthy of development. A flexible attitude, thus, allows us to take advantage of opportunities as they arise in the drawing process. While fluency and flexibility are important in the beginning of any creative endeavor, they must be coupled with reasoned judgment and selectivity. We must be able to generate choices without losing sight of our goal.



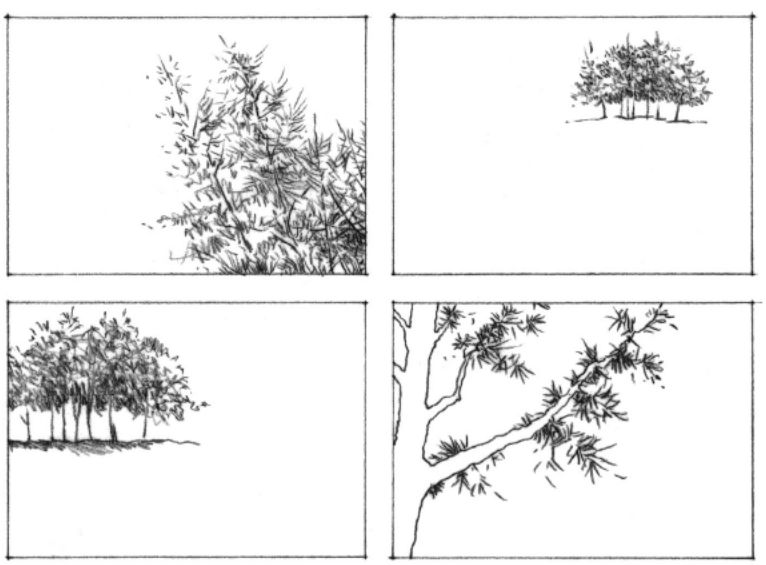


Shifting Viewpoints

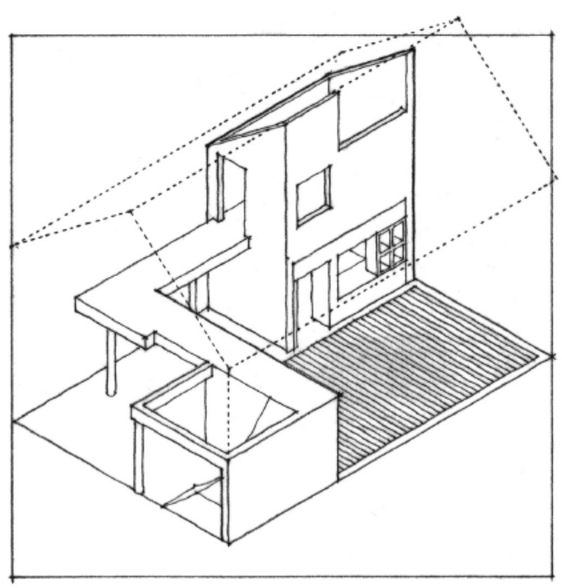


A creative imagination regards old questions from a new angle. Relying on habit and convention can impede the flow of ideas during the design process. If we can see in different ways, we are better able to see hidden opportunities in the unusual, the exceptional, and the paradoxical. To see in new ways requires a keen power of visualization and an understanding of the flexibility drawing offers in presenting new possibilities.
To see with a fresh eye, we can look at a mirror image of what we are drawing. We can turn the drawing upside down or stand back from it to study the visual essence of the image—its basic elements, pattern, and relationships. We can even see it through someone else's eyes. To encourage a shift in view, it is sometimes useful to use a different medium, a different paper, a different technique, or a different drawing system.

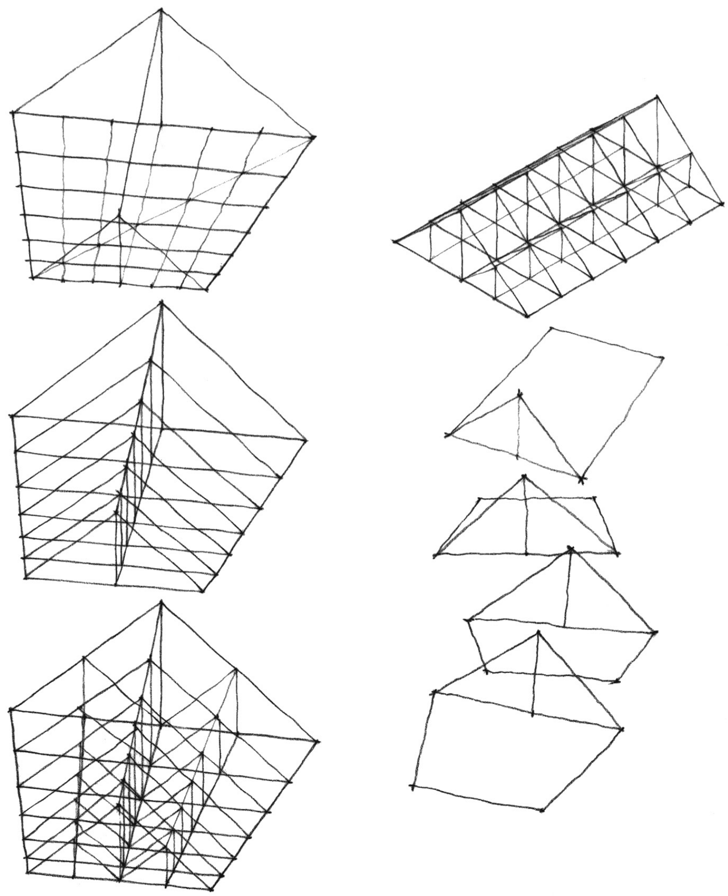
Drawing can stimulate our thinking by offering different points of view. Multiview, paraline, and perspective drawing systems compose a visual language of design communication. We must be able to not only write in this language but also to read it. This understanding should be thorough enough that we are able to work comfortably back and forth from one drawing system to another. We should be able to transform the flatness of a multiview drawing into a three-dimensional paraline view. Viewing a set of multiview drawings, we should be able to imagine and draw what we would see if we were to stand in a particular position in the plan view.



Vary the point of view.



See inside things.

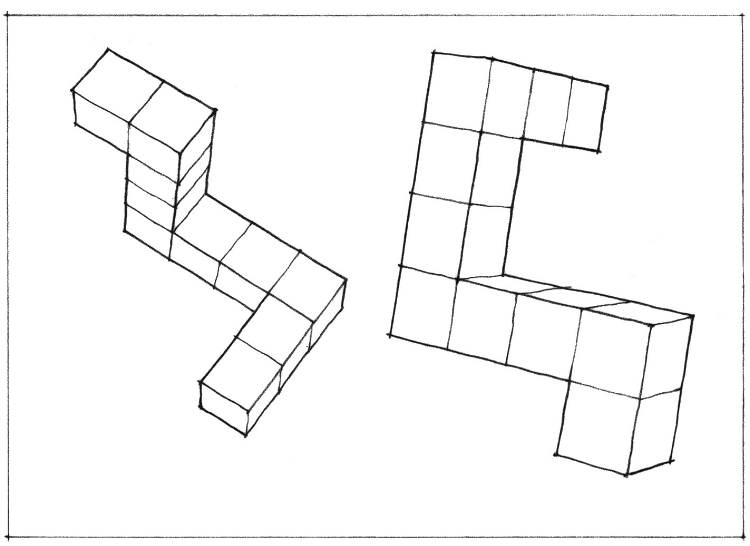


Rotating

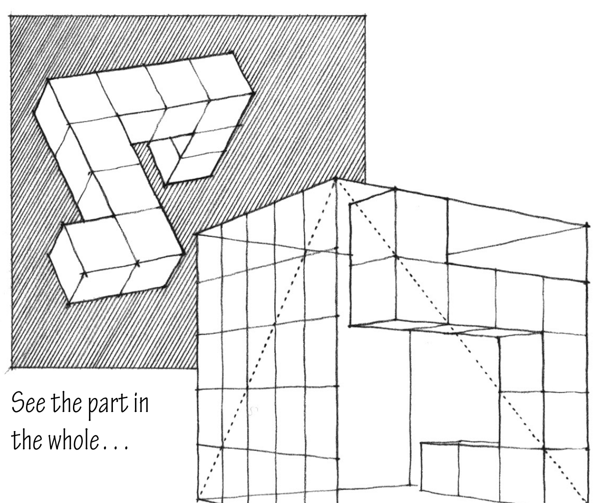
Turning an idea over in our mind enables us to see and study it from different points of view. In a similar fashion, if we can imagine how an object rotates in space, or how it might appear as we move around it, we can explore its many facets from all sides. Also, if we are able to manipulate a design idea on paper as we turn it over in our mind, we can more fully explore the multiple dimensions of a design idea.

When drawing how something rotates in space, it is much easier to imagine the revolution of a simple geometric element rather than an entire composition of parts. Therefore, we begin by establishing the ordering device that binds the form or composition together—whether it be an axis, a polygonal shape, or a geometric volume—and analyzing the principles that regulate how the parts are related to the whole.

We then imagine and draw how the ordering device might appear as it rotates and moves to a new position in space. Once we arrive at this new position, we reestablish the parts in proper relation and orientation to the whole. In building up the image, we use regulating lines to form the structure of the object or composition. After checking for accuracy of proportions and relationships, we add thickness, depth, and details to the framework to complete the drawing.



Turn an idea over in your mind.



See the part in the whole . . .

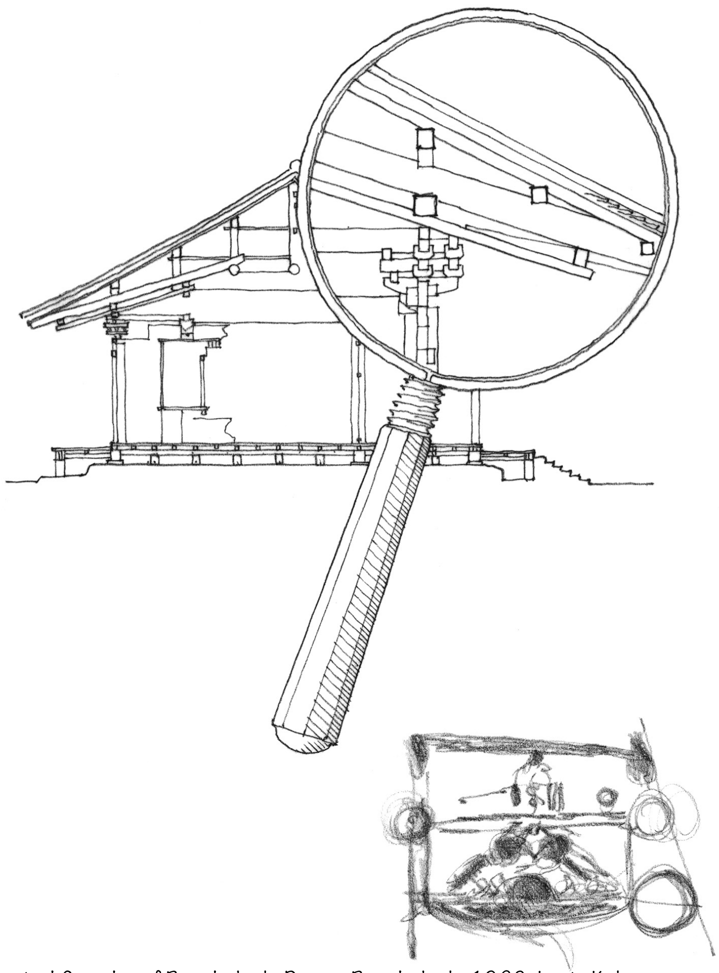
and the whole in the part.

Changing Scale

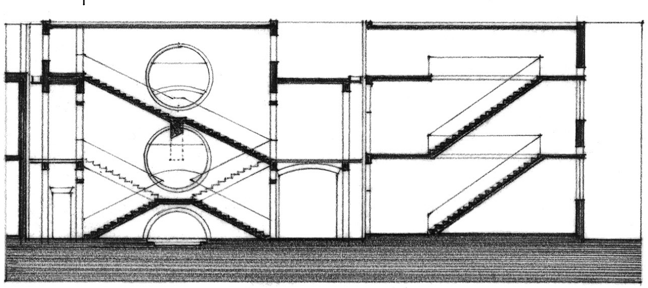
In working from the general to the particular, from the broad, overriding issues to the detailed resolution of a problem, we parallel the gradual formulation, refinement, and crystallization of a design. The graphic technique progresses in a corresponding manner from diagrammatic sketches executed in broad strokes to more definitive drawings of concrete ideas and solutions executed with more precise instruments.

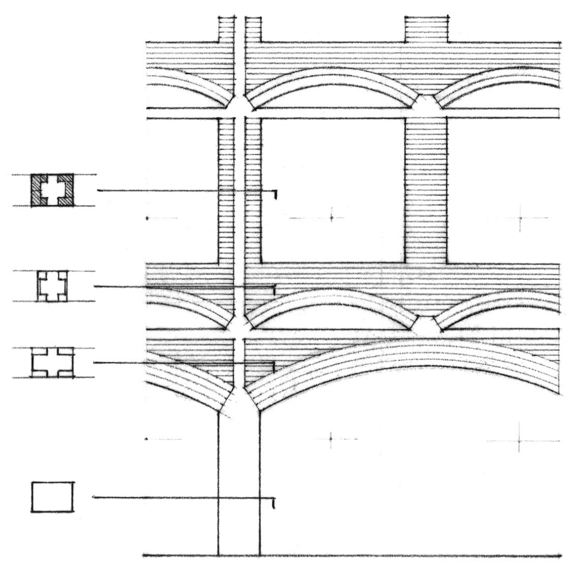
We stimulate our design thinking by working at various scales and levels of abstraction. The scale of a drawing establishes which aspects or features we can attend to and likewise those we must ignore. For example, the question of material goes unanswered at a small scale partly because we cannot represent material at that scale. At a larger scale, however, this question would arise. Unless the material question is resolved, such a drawing would seem too large for its content. Changing the scale of the drawings we use during the design process allows us to distill an idea down to essentials as well as expand the idea to incorporate issues of material and detail.

The interdependence of design issues and scale is a question not only of perception but also of craft. Our choice of a drawing medium depends on the scale of a drawing and determines the degree of representation or abstraction we are able to illustrate. For example, drawing with a fine-tipped pen would encourage us to draw small and enable us to attend to detail. Drawing with a broad-tipped marker, on the other hand, would allow us to cover more ground as well as study the broader issues of pattern and organization.



Capital Complex of Bangladesh, Dacca, Bangladesh, 1962, Louis Kahn. An early plan sketch, section through the stair gallery, and a detail of the composite wall construction.



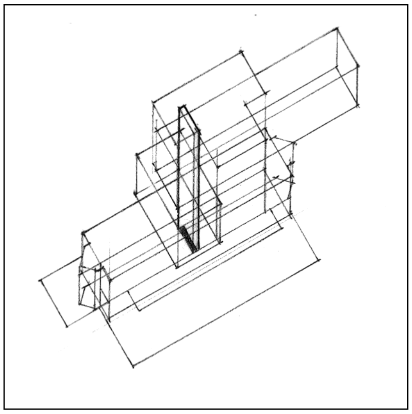


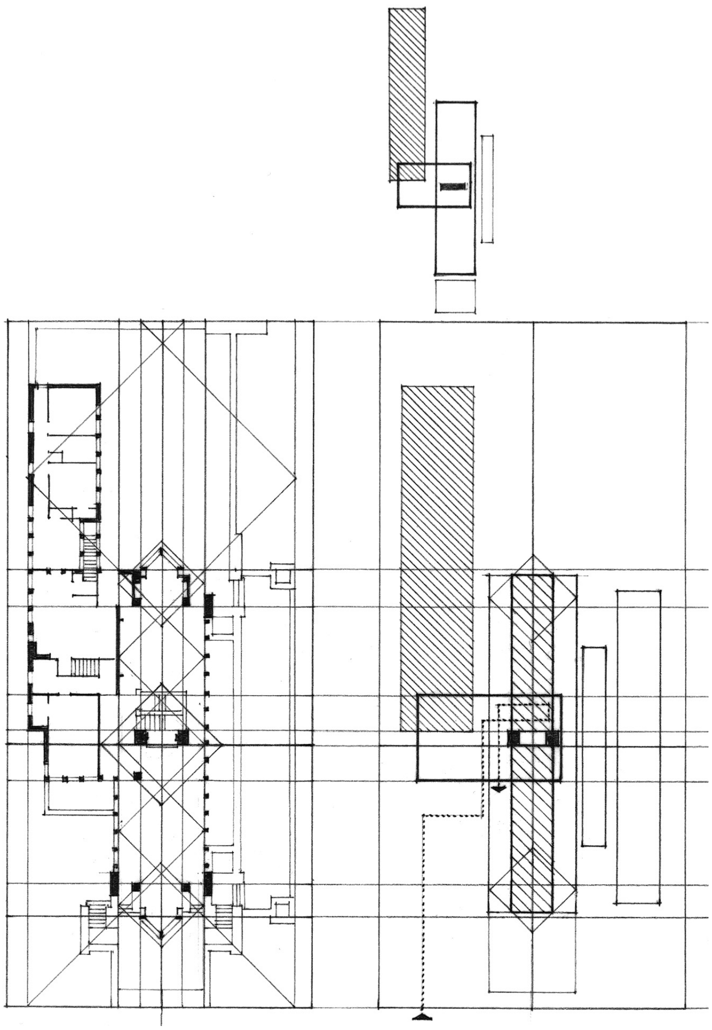
Diagramming

No drawing is ever the thing it endeavors to represent. All drawings are to some degree abstractions of a perceived reality or an imaginary conception. In design drawing, we operate at varying levels of abstraction. At one end of the spectrum lies the presentation drawing, which attempts to simulate as closely as possible the future reality of a design proposal. At the other end is the diagram, which has the ability to describe something without representing it in a pictorial way.

A diagram is any drawing that explains or clarifies the parts, arrangement, or operation of something. The hallmark of a diagram is its ability to simplify a complex notion into essential elements and relationships by a process of elimination and reduction. Professionals in many different fields use diagrams to expedite their thinking. Mathematicians, physicists, and even musicians and dancers use their own abstract languages of symbols and notations to deal with the complexities of their endeavors. Designers, too, use diagrams to stimulate and clarify their visual thinking.

While every design process must eventually converge on a solution to a problem, the beginning phases should be characterized by divergent thinking about possibilities. Design involves making choices; without alternatives, there is no choice to be made. By focusing on the general rather than the particular, diagrams discourage closing on a solution too quickly and encourage the exploration of possible alternatives. The activity of diagramming, therefore, provides a convenient way to think about how to proceed in generating a series of viable alternatives to a given design problem. Their abstract nature enables us to analyze and understand the essential nature of program elements, to consider their possible relationships, and to seek ways in which these parts can be organized to make a unified whole.

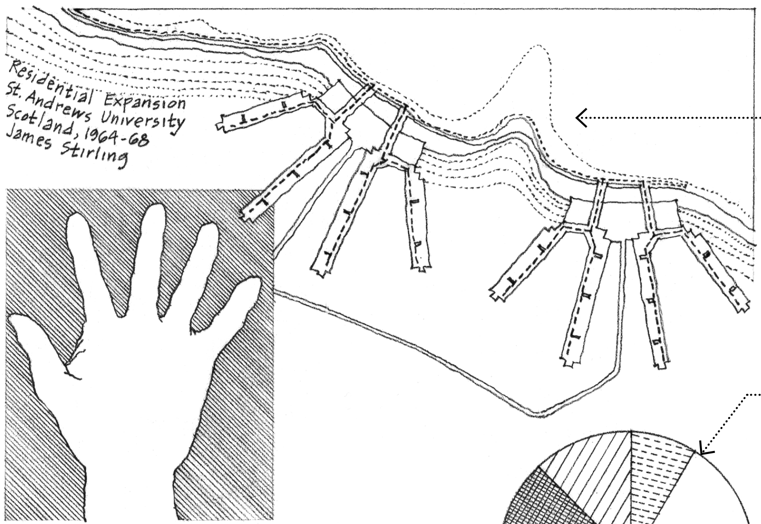




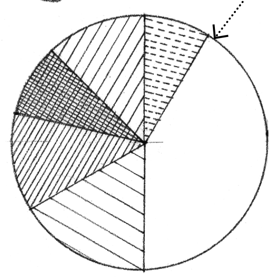
Analysis of the Robie House, Chicago, 1909, Frank Lloyd Wright

Types of Diagrams

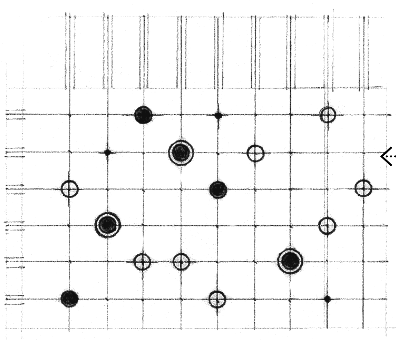
Designers use a number of diagram types throughout the design process to initiate, clarify, and assess an idea.



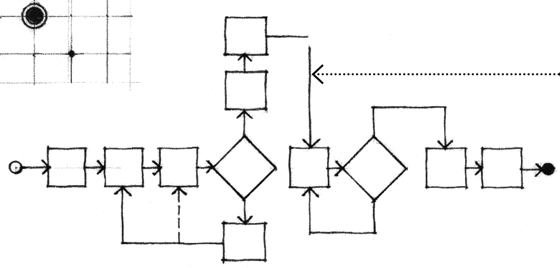
- Graphic metaphors depict visual analogies in the idea-generating phase of the design process, suggesting solutions without preconceiving a final form.



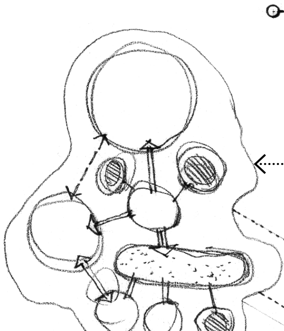
- Area diagrams communicate information about the size, degree, or magnitude of elements. Common types of area diagrams include bar graphs, pie charts, and intensity maps.



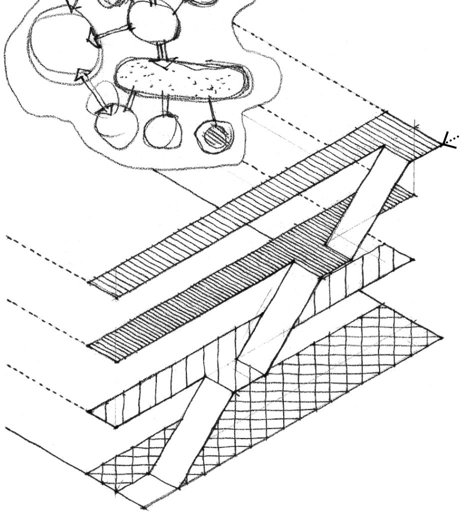
- Matrix diagrams use a coordinate system to quantify and correlate adjacencies and degrees of importance between elements, especially in the program-analysis phase of design.



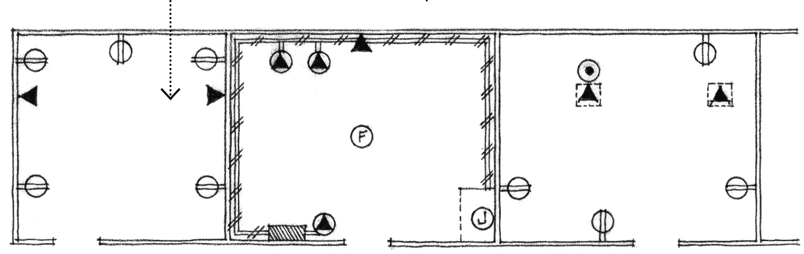
- Network diagrams describe the successive steps in a process, procedure, or operating system. Specific types of network diagrams often associated with the critical path method are flow charts and tree diagrams in which the selection of each branch requires that a logical decision be made.



- Bubble diagrams illustrate the relative sizes and desirable proximities of functional zones and activities, which can point to possible geometric patterns of a design solution.



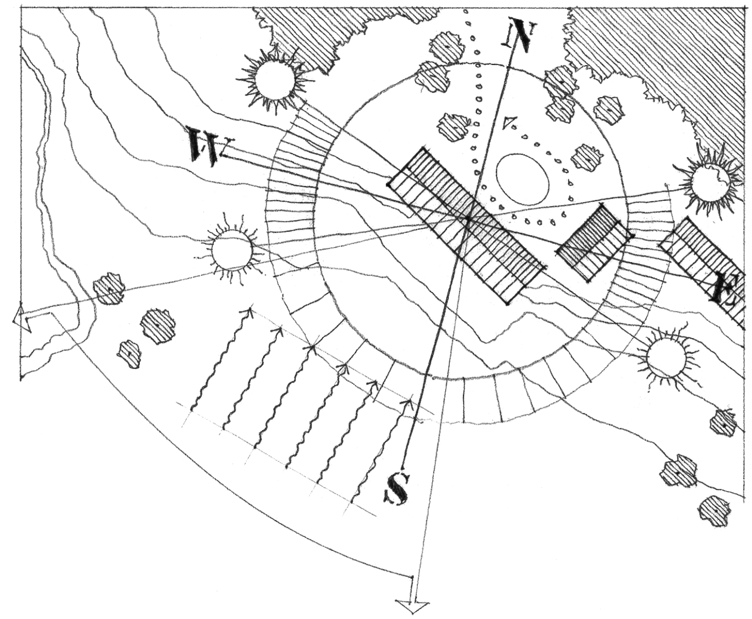
- Circulation diagrams are flow diagrams that describe the nodes and patterns of movement of people, vehicles, and services.

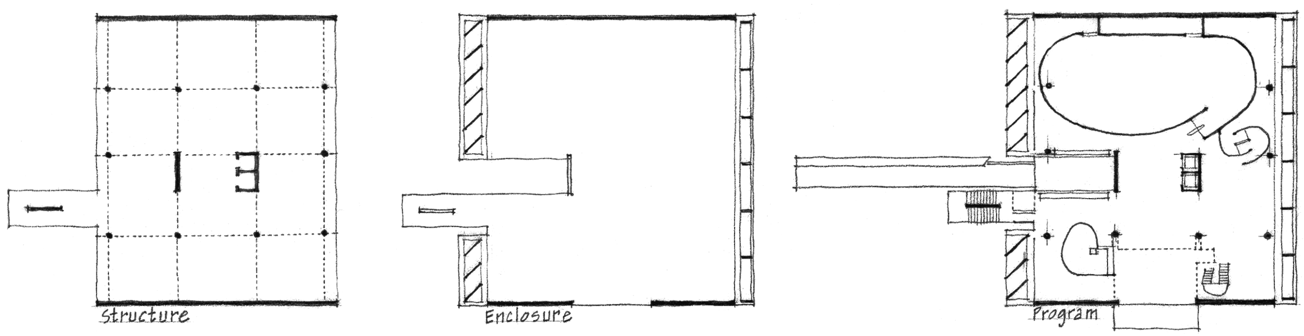


- Schematics are diagrams that illustrate the layout and coordination of electrical and mechanical components and systems.

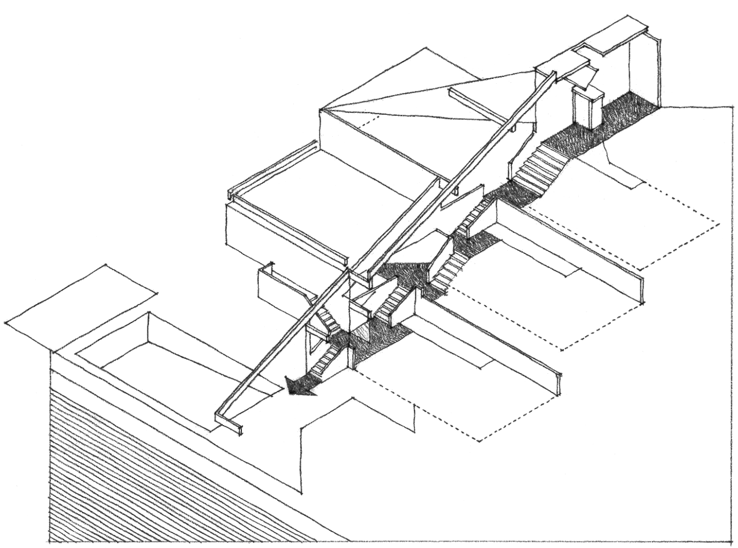
Analytical Diagrams

Analytical diagrams examine and explain the arrangement and relations of the parts of a whole. We use a variety of analytical diagrams in design. Site analyses explore how the siting and orientation of a design respond to environmental and contextual forces. Program analyses investigate how a design organization addresses programmatic requirements. Formal analyses examine the correspondence between structural pattern, spatial volumes, and elements of enclosure.





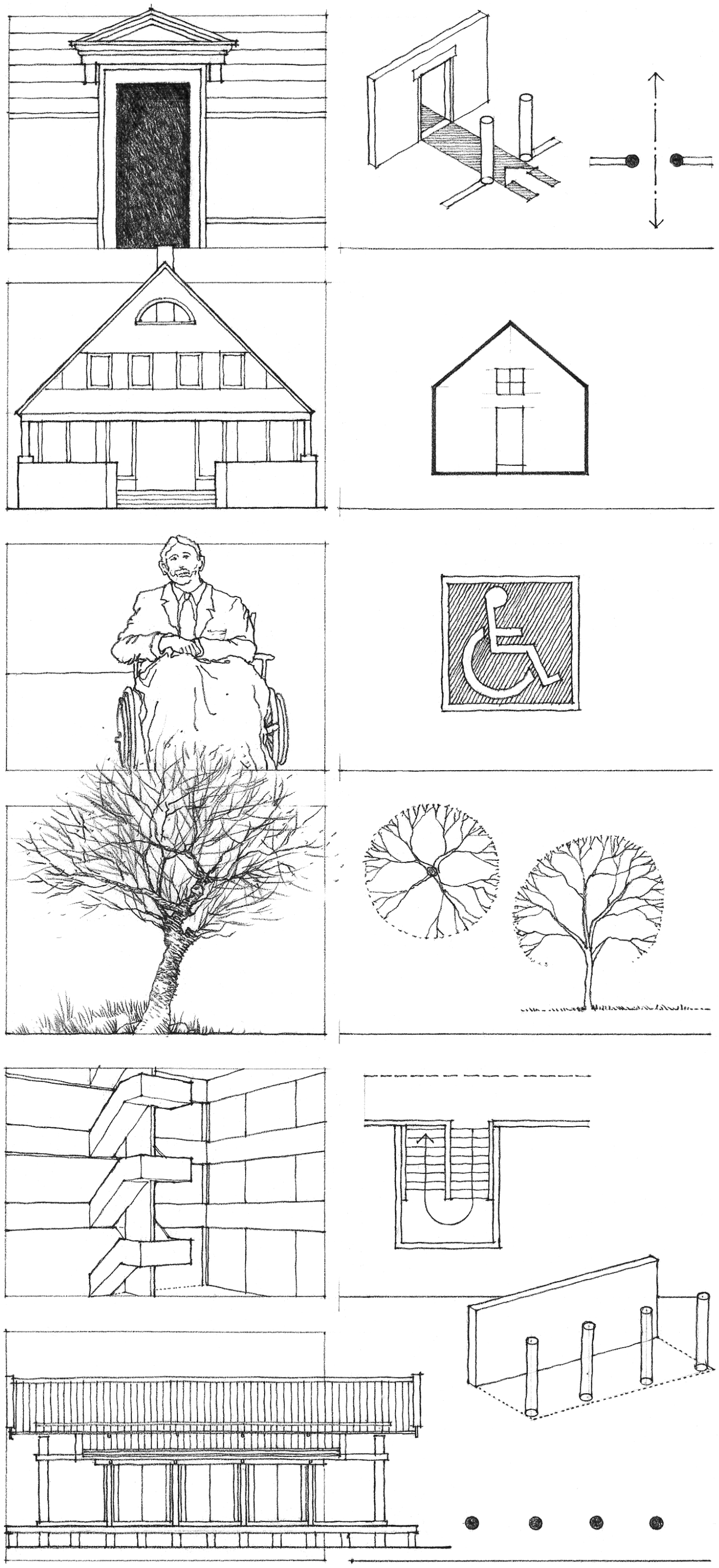
Millowners' Association, Ahmedabad, India, 1954, Le Corbusier



We can use any of the drawing systems to define the viewpoint of a diagram. When a diagram isolates a single issue or set of relationships for study, a two-dimensional format is usually sufficient. However, when we begin to explore the complex spatial and relational attributes of a design, a three-dimensional drawing system becomes necessary. Particularly effective vehicles for studying the volumetric massing and spatial dimensions of a design are cutaway, expanded, and phantom views.

Diagramming Elements

The efficiency of using diagrams to study, analyze, and make design decisions results from their use of signs and symbols. These abstract figures represent more complex entities, actions, or ideas in a form more suitable for editing, manipulation, and transformation than representational images. Their use allows us to respond to the swift and speculative nature of thought during the design process.

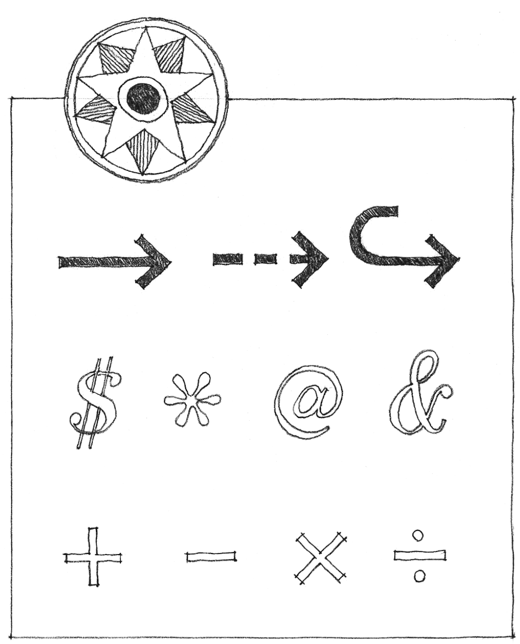


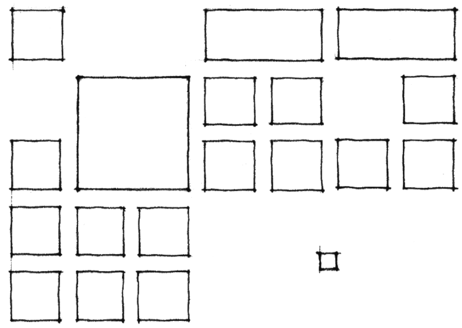
Symbol

A symbol is a graphic figure that stands for something else by association, resemblance, or convention, deriving its meaning chiefly from the structure in which it occurs. Representational symbols are simplified pictures of what they represent. To be useful and meaningful to a broad audience, they must be generalized and embody the structural features of what they refer to. Highly abstract shapes, on the other hand, can be very broad in application, but usually need a context or caption to explain their meaning. When symbols become more abstract and lose any visual connection to what they refer, they become signs.

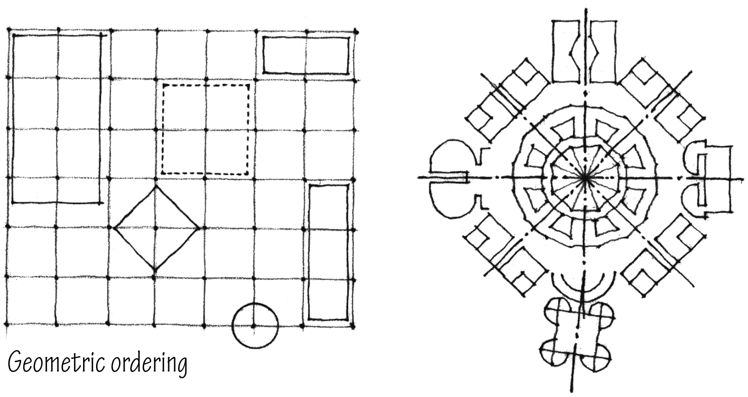
Sign

A sign is a graphic symbol, figure, or mark that has a conventional meaning and is used as an abbreviation for the word, phrase, or operation it represents. Signs do not reflect any of the visual characteristics of its referent. They can be understood only by convention or common agreement.

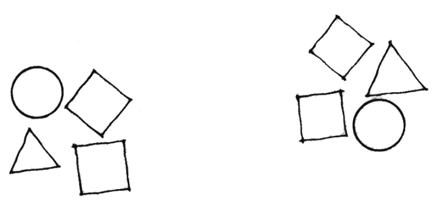


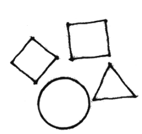


Hierarchy by size



Geometric ordering



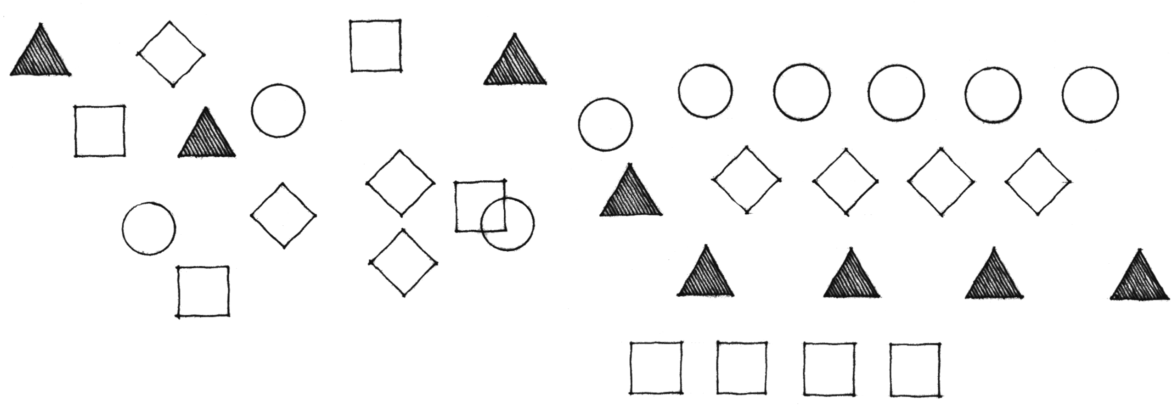


Organizing by proximity

Symbols and signs are not as suitable as words in expressing subtle degrees of difference or slight nuances of meaning; nevertheless they efficiently communicate the identity of elements and the nature of actions or processes. Such visual abstractions can often communicate ideas more swiftly than is possible through words alone. Even so, we often use explanatory text to clarify the symbols of a diagram, even if only in the abbreviated form of a key or legend.

We can modify the graphic display and meaning of symbols and signs by altering the following characteristics:

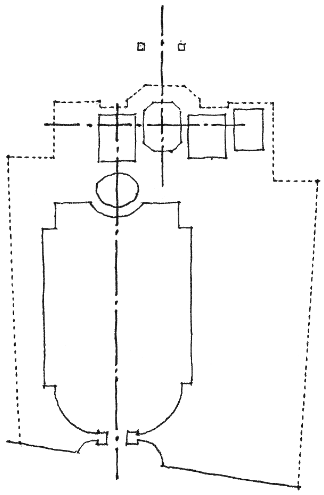
- The relative size of each symbol or sign can describe quantifiable aspects of each element as well as establish a hierarchical ranking among the elements.
- A grid or other geometric ordering device can regulate the positioning and layout of entities or subjects within the field of the diagram.
- Relative proximities indicate the intensity of relationship among entities. Elements in close proximity to each other convey a stronger relationship than more distant ones.
- Similarities and contrasts of shape, size, or tonal value establish categories among selected objects or ideas.
- Reducing the number of elements and variables helps maintain an appropriate and manageable level of abstraction.

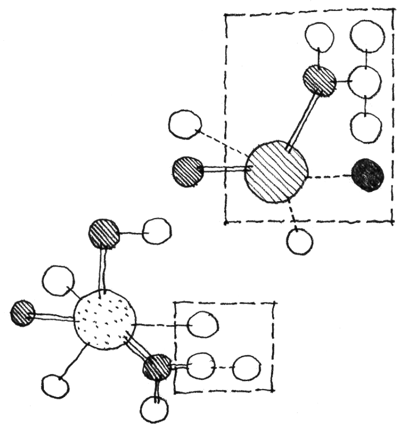


Categorizing by similarity and contrast

Diagramming Relationships

To make the relationships among the elements of a diagram more visible, we use the grouping principles of proximity, continuity, and similarity. To further clarify and emphasize specific types of linkages or the nature of interactions among the entities, we can employ a variety of lines and arrows. By varying the width, length, continuity, and tonal value of these linking elements, we can also describe varying degrees, levels, and intensities of connection.



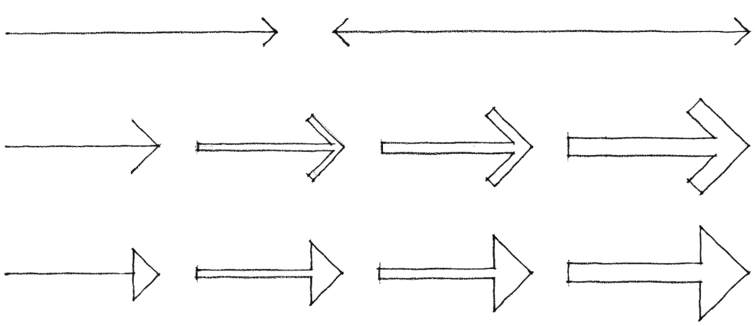


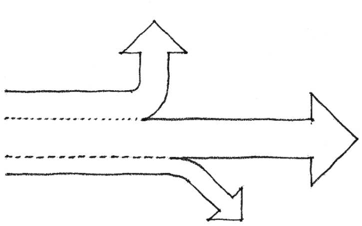
Lines

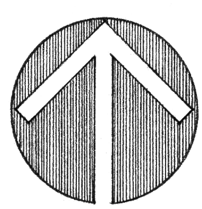
We use the organizing power of lines in diagramming to define the boundaries of fields, denote the interdependencies of elements, and structure formal and spatial relationships. In clarifying the organizational and relational aspects of a diagram, lines make both abstract and pictorial concepts visible and understandable.

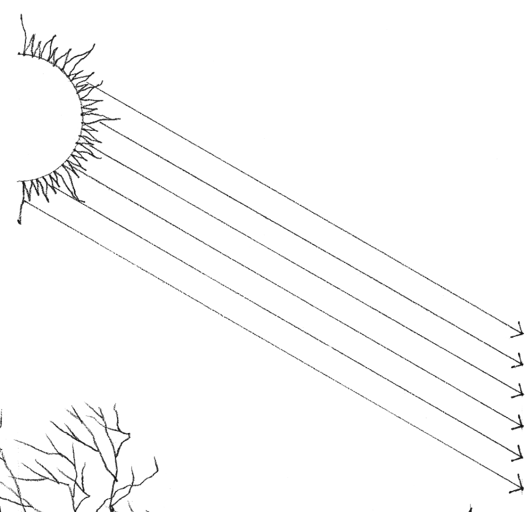
Arrows

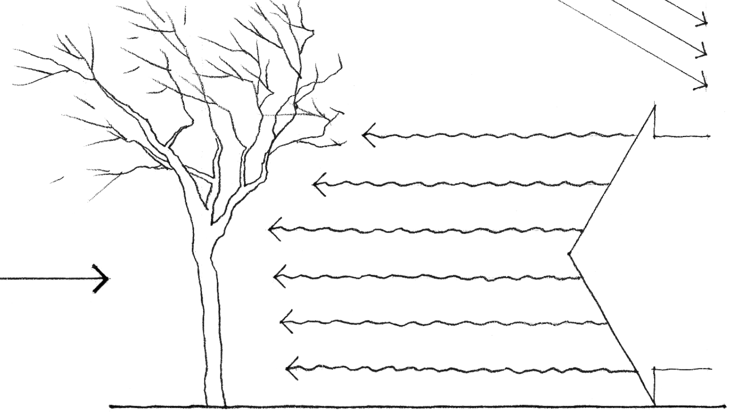
Arrows are a special type of connecting line. The wedge-shaped ends can signify one- or two-way movement from one element to another, indicate the direction of a force or action, or denote the phase of a process. For clarity, we use different types of arrows to distinguish between the types of relationships as well as varying degrees of intensity or importance.

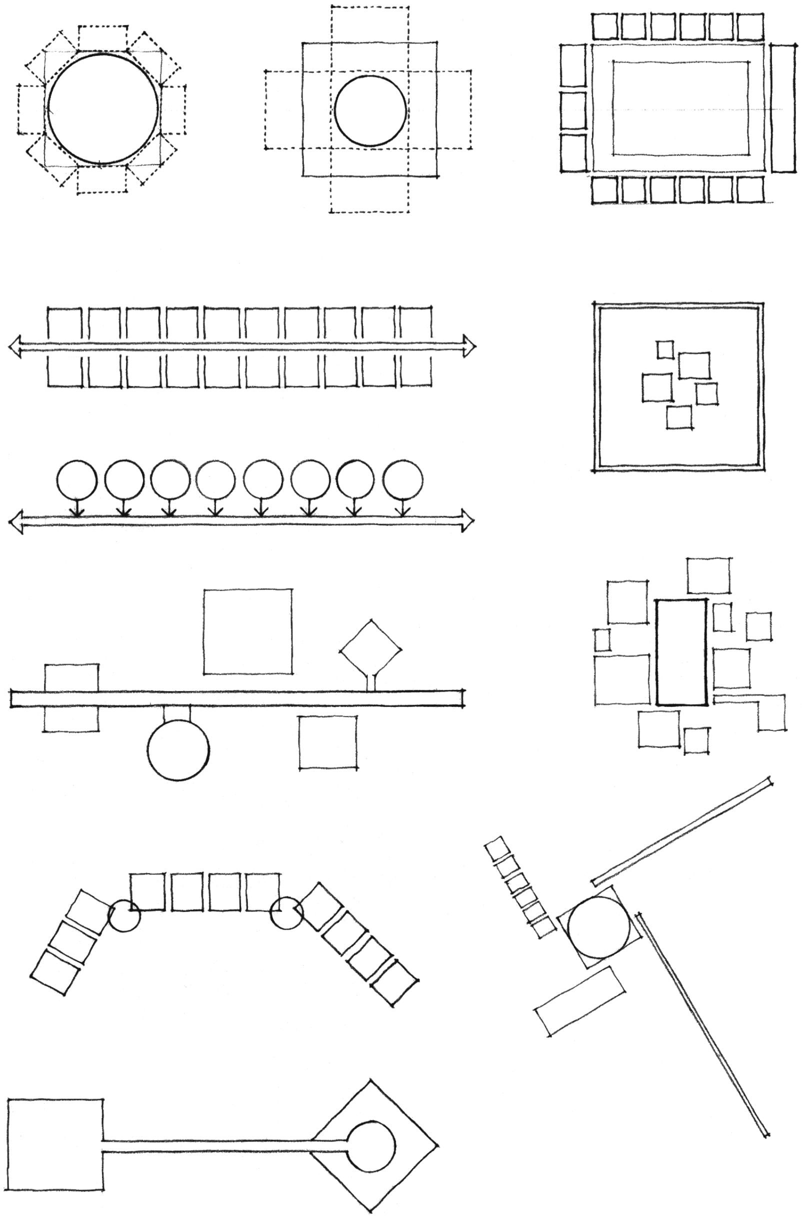












Diagramming Concepts

We use diagrams in the initial stages of the design process to study existing conditions and to generate, explore, and clarify concepts. We also use diagrams in the presentation phase of the design process to explain the conceptual basis for a design proposal.

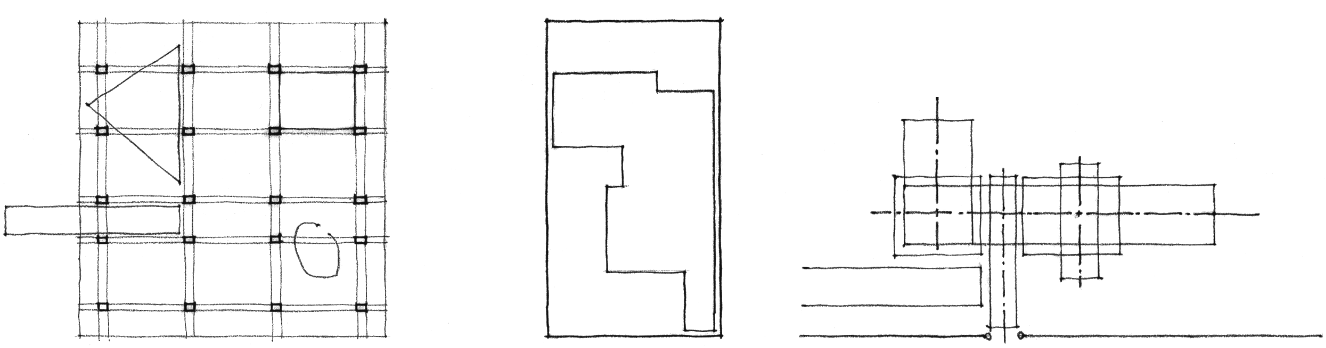
Parti

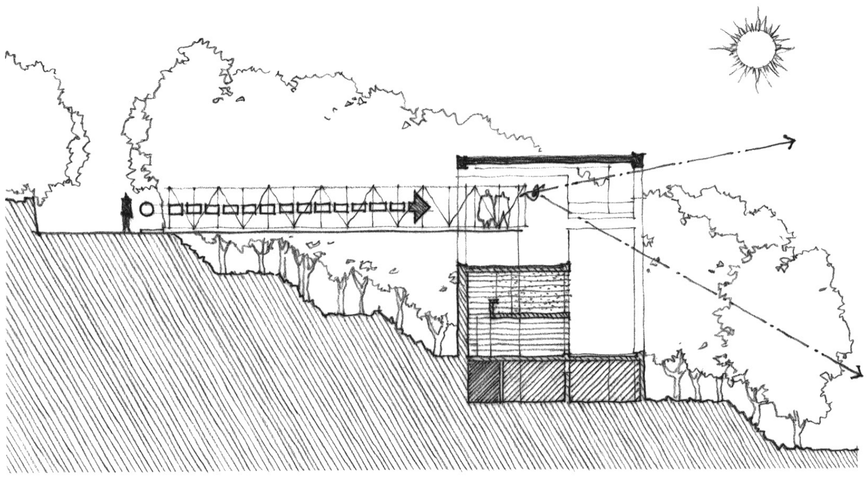
A concept is a mental idea or image capable of generating and guiding the development of a design. We use the term parti when referring to the concept or primary organizing idea for an architectural design. Drawing out a concept or parti in diagrammatic form enables a designer to quickly and efficiently investigate the overall nature and organization of a scheme. Instead of concentrating on how a design might appear, the concept diagram focuses on the key structural and relational features of an idea.

A suitable concept should of course be appropriate and relevant to the nature of the design problem. In addition, both a design concept and its graphic portrayal in a diagram should have the following characteristics.

A concept diagram should be:

- Inclusive: capable of addressing the multiple issues of a design problem
- Visually descriptive: powerful enough to guide the development of a design
- Adaptable: flexible enough to accept change
- Sustainable: able to endure manipulations and transformations during the design process without a loss of identity



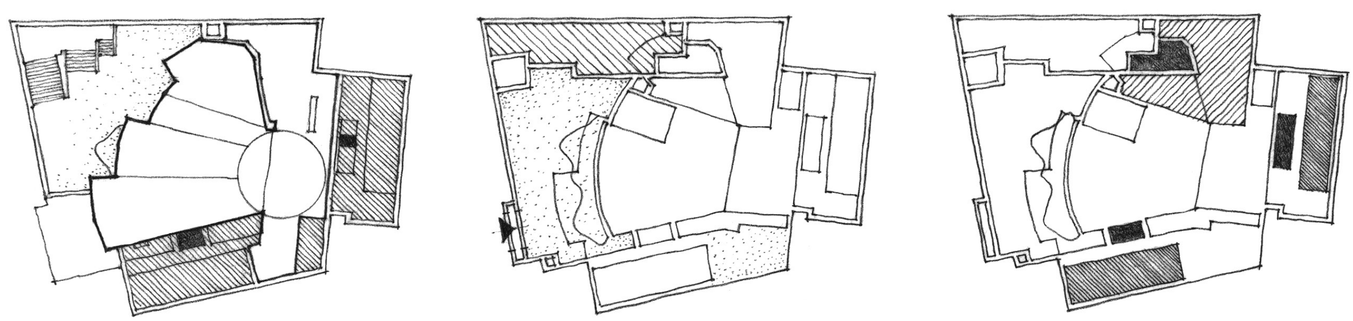


Residence at Riva San Vitale, on the shore of Lugano Lake, Switzerland, 1971–1973, Mario Botta

Some of the design issues that concept diagrams can effectively address include:

Site

- Contextual constraints and opportunities
- Historical and cultural influences
- Environmental forces of sun, wind, and precipitation
- Topography, landscape, and water features
- Approach, access, and paths through a site



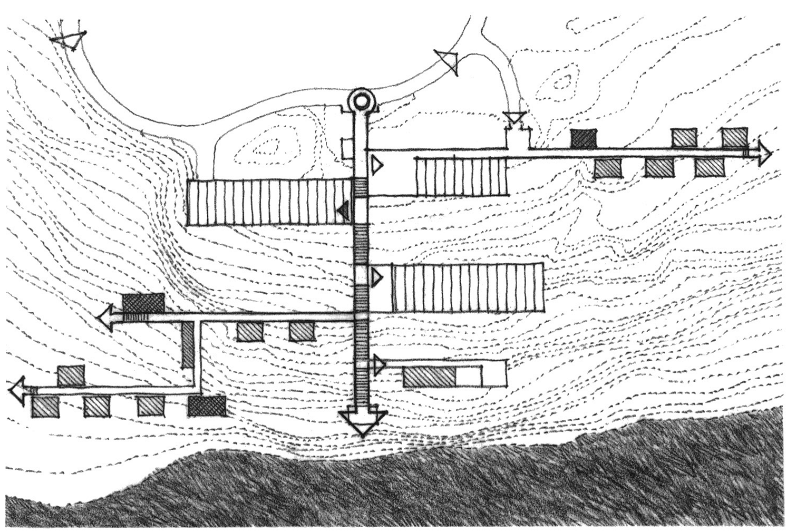
Theater in Seinäjoki, Finland, 1968–1969, Alvar Aalto

Program

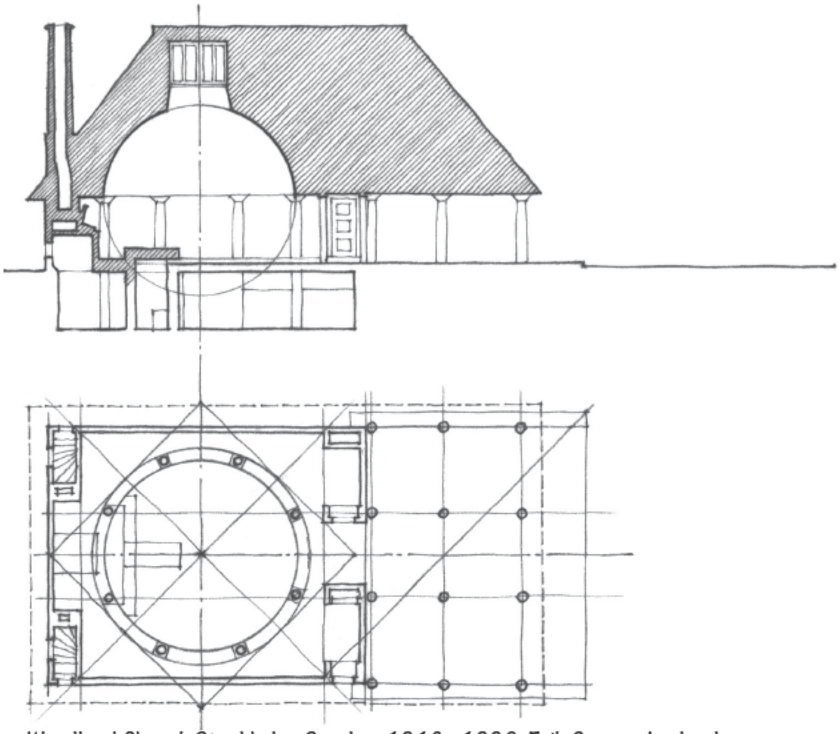
- Spatial dimensions required for activities
- Functional proximities and adjacencies
- Relationship between served and service spaces
- Zoning of public and private functions

Circulation

- Pedestrian, vehicular, and service paths
- Approach, entry, nodes and paths of movement
- Horizontal and vertical modes of travel



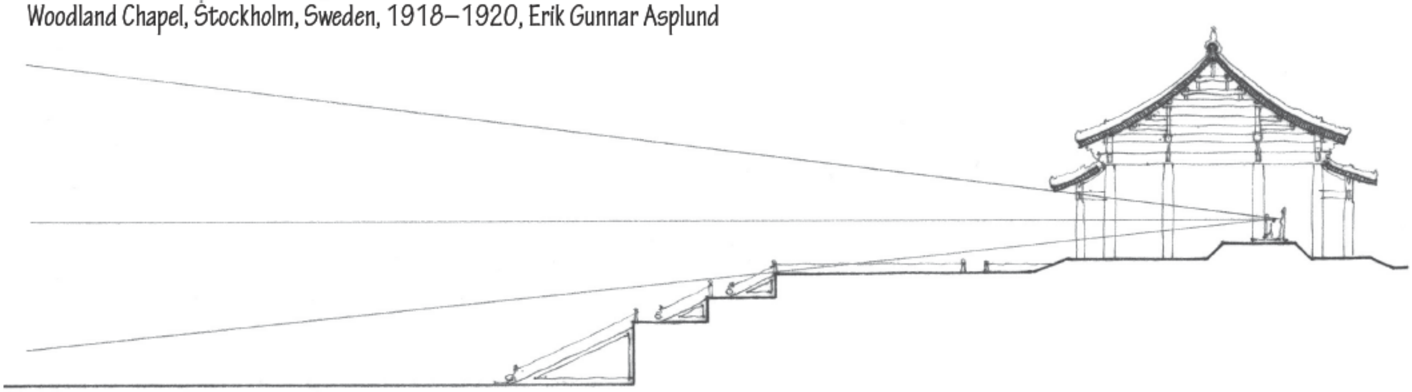
Haystack Mountain School of Arts and Crafts, Deer Isle, Maine, 1960, Edward Larabee Barnes



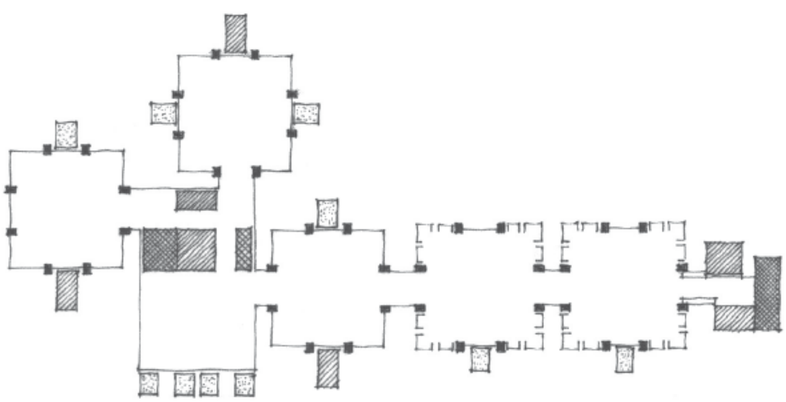
Woodland Chapel, Stockholm, Sweden, 1918–1920, Erik Gunnar Asplund

Formal Issues include:

- Figure-ground and solid-void relationships
- Ordering principles, such as symmetry and rhythm
- Structural elements and pattern
- Elements and configuration of enclosure
- Spatial qualities, such as shelter and outlook
- Hierarchical organization of spaces
- Formal massing and geometry
- Proportion and scale



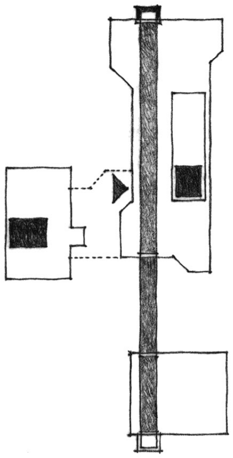
Pavilion of Supreme Harmony (Taihe Dian) in the Forbidden City, Beijing (Peking), 1627



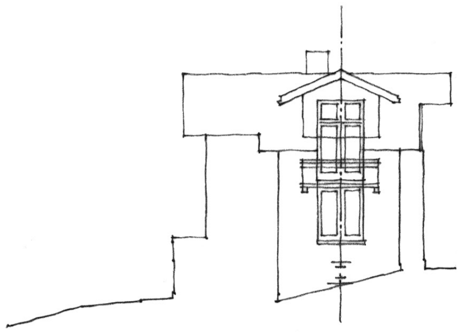
Richards Medical Research Laboratory, University of Pennsylvania, Philadelphia, 1957–1961, Louis Kahn

Systems

- Layout and integration of structural, lighting, and environmental control systems



Hines House, Sea Ranch, California, 1966, MLTW

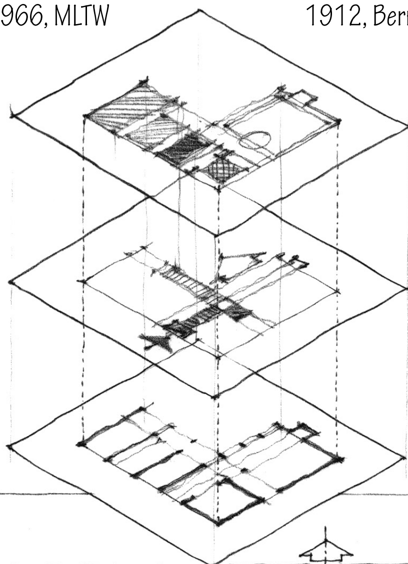


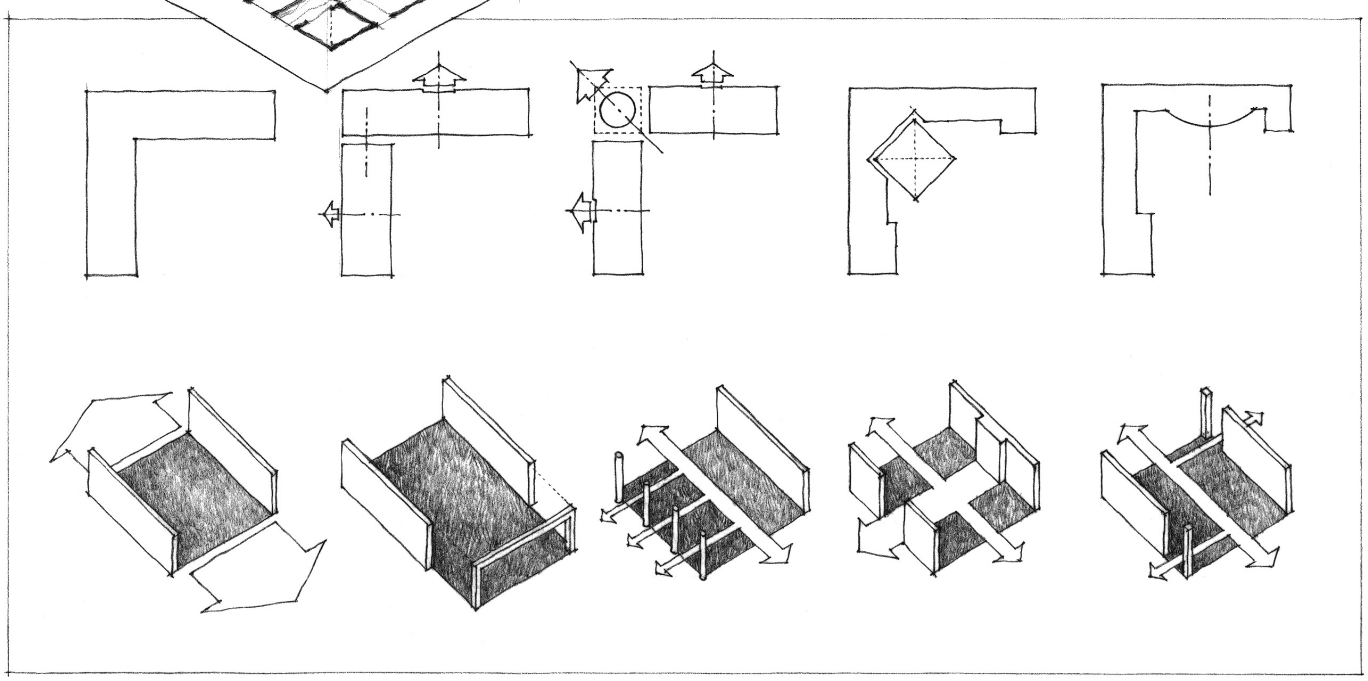
Flagg House, Berkeley, California, 1912, Bernard Maybeck

In generating, developing, and using concept diagrams, certain principles can help stimulate our thinking.

- Keep concept diagrams concise. Drawing small condenses the information to a manageable level.
- Delete extraneous information as needed to focus on a particular issue and enhance the overall clarity of the diagram.
- Overlay or juxtapose a series of diagrams to see how certain variables affect the nature of a design, or how the various parts and systems of a design fit together to form a whole.
- Reverse, rotate, overlap, or distort an element or linkage in order to provide new ways of viewing the diagram and to discover new relationships.
- Use the modifying factors of size, proximity, and similarity to reorganize and prioritize the elements as you search for order.
- Add relevant information when necessary to take advantage of newly discovered relationships.

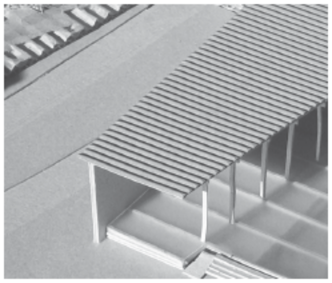
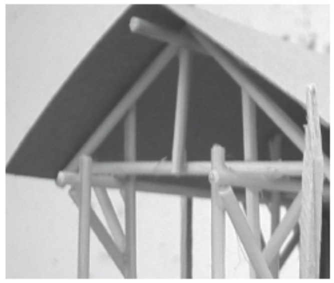
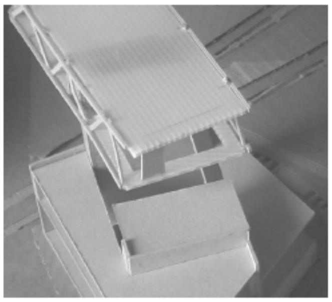
In all cases, the visual clarity and organization of the diagram should please the eye as well as impart information to the viewer.





Modeling

Physical Models

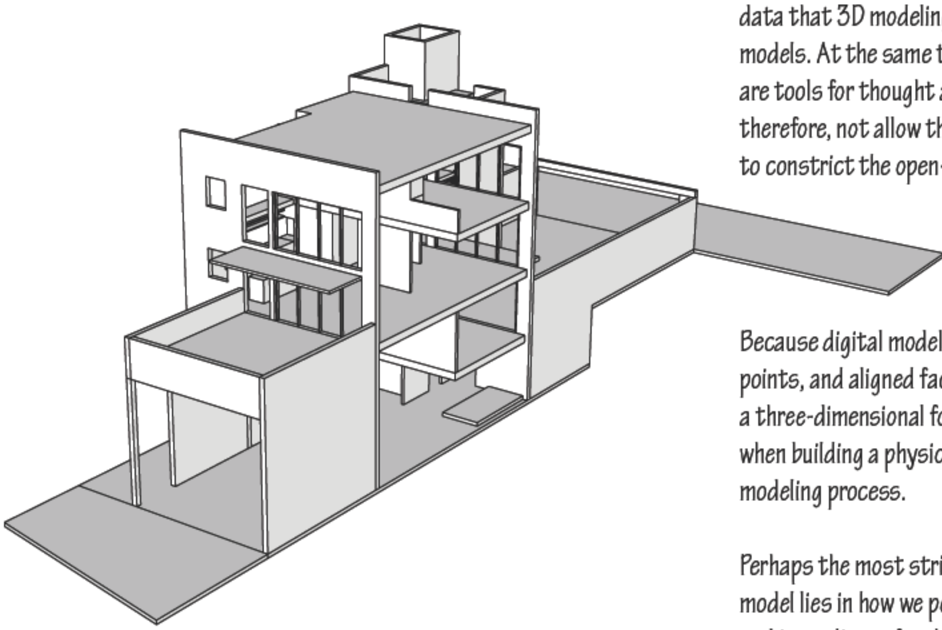





Physical study models, like process drawings, are important for quickly visualizing a design idea. Working with our hands in cutting and assembling real materials provides a tactile sensibility that augments the purely visual and gives it a spatial dimension. While they can often be used as a presentation device, physical study models should be seen primarily as a means of exploration. Once constructed, physical models can be turned in our hands and our head, torn apart, and remodeled. They can be photographed from different points of view and the photographic images scanned for digital explorations or printed out and drawn over.

Digital Models

3D modeling programs enable us to build virtual models of our design ideas and study them from various points of view. This makes them viable for developing concepts as long as one sees the modeled images as works in progress rather than as finished products.

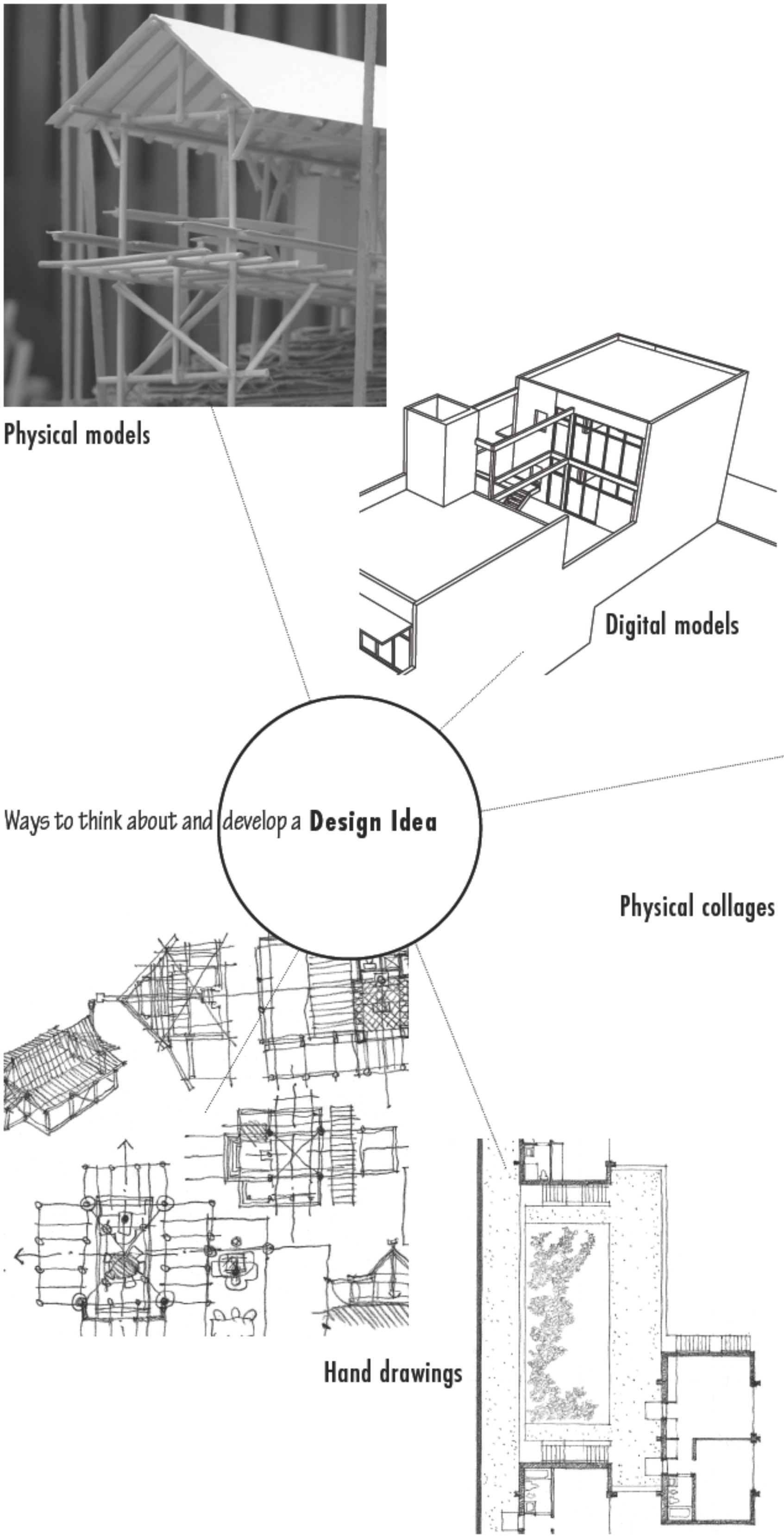
Working with digital models requires control over the exactness of data that 3D modeling programs expect in the creation of digital models. At the same time, we should keep in mind that digital models are tools for thought and subject to change and revision. We should, therefore, not allow the degree of specificity in both input and output to constrict the open-endedness of the design process.



Because digital modeling relies heavily upon the use of axes, tangent points, and aligned faces and edges as construction aids to develop a three-dimensional form, thinking in these terms—as we would when building a physical model—generally results in a more efficient modeling process.

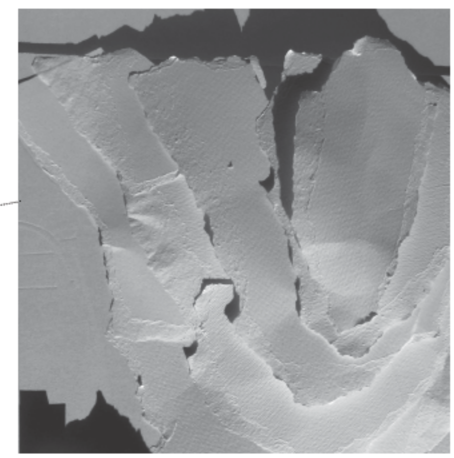
Perhaps the most striking difference between a physical and a digital model lies in how we perceive the materiality, spatial characteristics, and immediacy of a physical model versus how a digital model must, at least with the technology available to us today, be viewed on a monitor or screen—essentially a 2D image of a 3D data set, which requires the same interpretive skills as when reading a hand drawing.

Developing Concepts



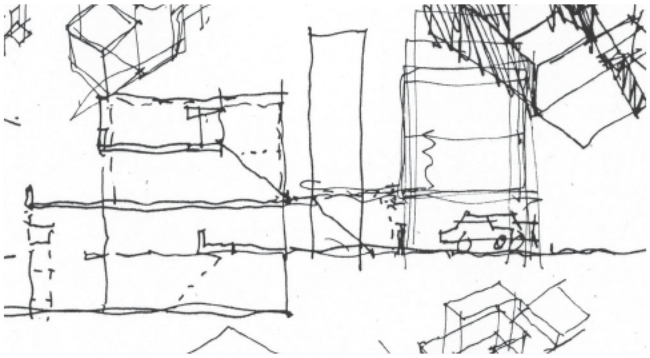
Design Process

While the design process is typically presented as a linear series of steps, it is more truly a cyclical, iterative sequence of careful analysis of available information, intuitive synthesis of insights, and critical evaluation of possible solutions—a process that is repeated until a successful fit between what exists and what is desired is achieved. The design process can be compressed into a short, intense period of time or extend over several months or even years, depending on the urgency or complexity of the design problem. Design can also be an untidy process in which moments of confusion are followed by instances of exquisite clarity, interspersed with periods of quiet reflection. To work our way through this process, from diagramming to the development and refinement of design ideas, we rely on various modes of representation.



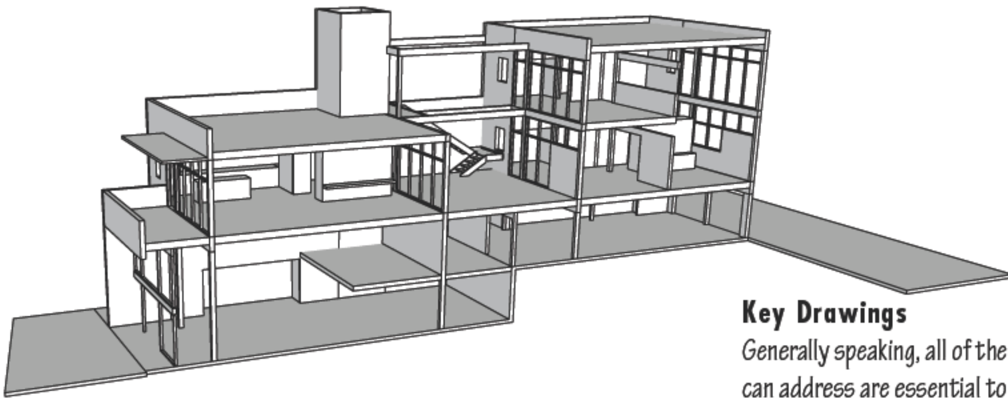
Modes of Representation

We can use various modes of representation to externalize and give form to our design ideas for study, analysis, and development. These include not only the traditional drawing conventions but also photography, physical collages and models, and digital explorations and simulations, all means by which we can effectively nurture the life of a design idea. There is no one mode of representation that is best suited for any particular phase of the design process. Neither is there a best practice for the way each of us approaches the design process.



Process Drawings

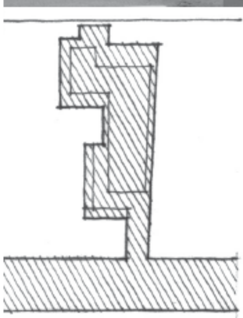
Once an appropriate and fertile design idea is identified and clarified, we use process drawings to advance and evolve the idea from a diagrammatic concept to a firm proposal. As we do so, we should remind ourselves that design drawing is a language and that the three major drawing systems—multiview, paraline, and perspective drawings—provide alternative ways to thinking and expressing about we are envisioning. Each system presents a unique point of view and involves a built-in set of mental operations that directs our exploration of relevant design issues. In selecting one drawing system over another to study a particular design issue, we make conscious as well as unconscious choices as to which aspects of the issue will be revealed and which will be concealed.

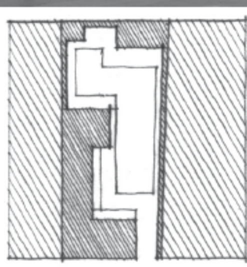


Key Drawings

Generally speaking, all of the design issues that concept diagrams can address are essential to the successful resolution of design problems. In any given situation, however, one or two of the issues may rise in significance above the others and form the core of a design idea or scheme, around which design solutions might be developed. Based on the nature of these key issues, one can identify corresponding key diagrams and drawings that offer the most appropriate and relevant ways of looking at and exploring these pivotal issues.

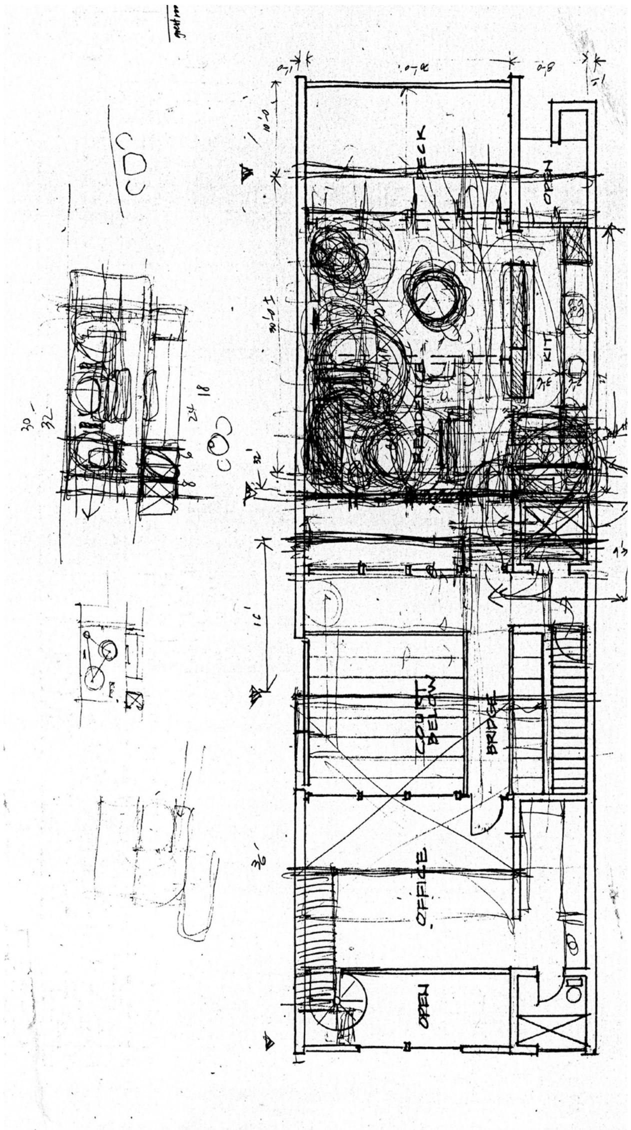
The key diagrams used in developing a design concept naturally lead to the use of the same key drawings in the presentation of the design proposal. In this sense, the presentation phase should not be seen as a separate and disconnected stage but rather a natural evolution of the design development process.





Site and Context Matter

Some design problems are dominated by site and context and are best explored through such representations as aerial photographs, site maps, and site sections. In urban situations particularly, the analysis and synthesis of figure-ground patterns, paths of movement, locations of nodes, axes and edges, as well as the presence of historical remnants or artifacts and perceptual lines of sight and view. All call for a representation of existing conditions over which the analysis and synthesis of these urban forces can be played out. For topographically interesting sites, contour maps and site sections provide the best platform on which to study the implications of topography on site access and building structure and form.

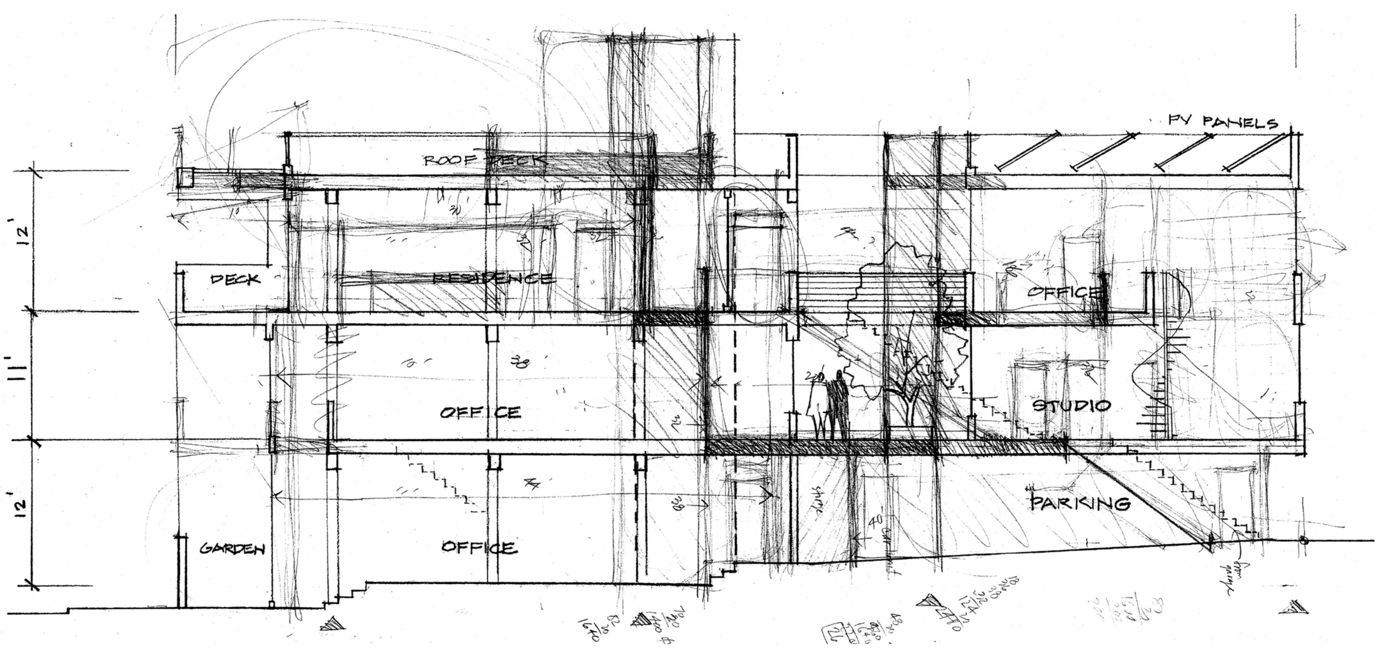


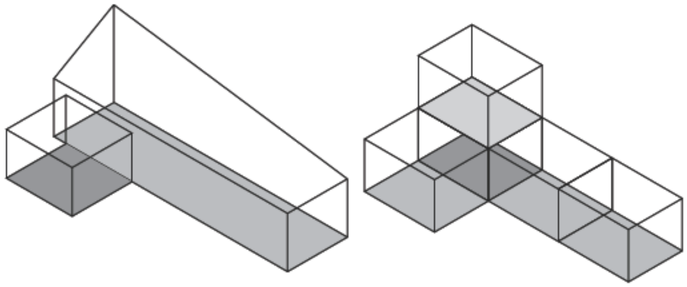
Programmatic Issues Matter

By outlining user and activity requirements, the design program gives life to a building design. In analyzing program requirements, we should be careful not to equate the ad hoc form of a bubble or relational diagram to the resulting form of a building design. In moving forward from any program analysis, we should rely instead on informing, infusing or overlaying any program analysis with formal and structural insights.

Size, Scale, and Proportion Matter

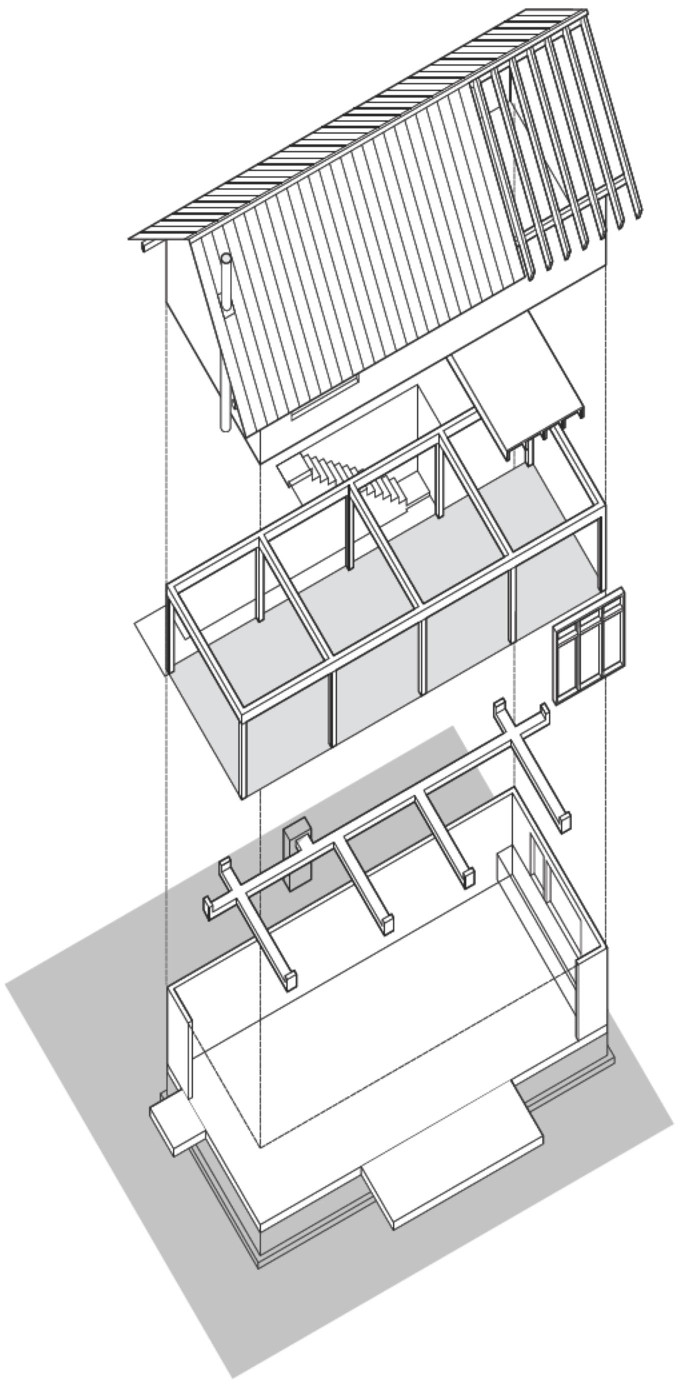
It is especially important to be mindful of size, scale, and proportion. The required size of a program space can be achieved in any number of ways. For example, a 400-square-foot space could be square, rectangular, or elongated into a gallery-like space. Or it could be irregular in shape or have curvilinear boundaries. Among all of these choices, how can we make a decision without referring to other factors, such as fit with other spaces, contextual opportunities and constraints, structural materials and form, and associated expressive qualities?

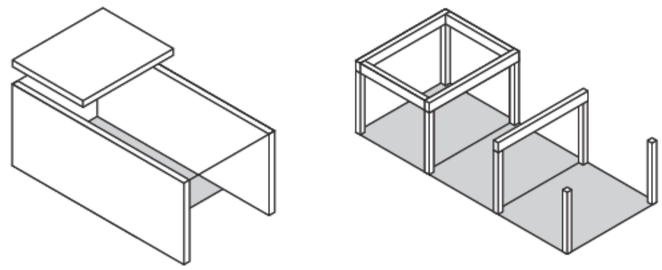


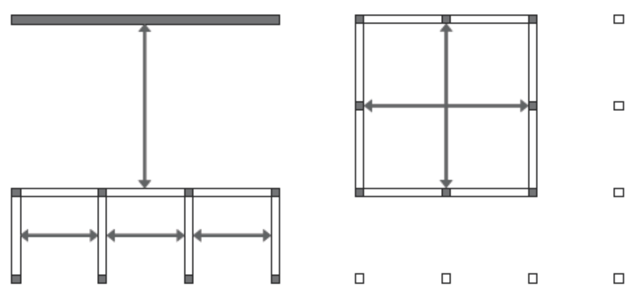


Structural Materials and Systems Matter

An understanding of how structural elements and systems resolve the forces acting on them, along with a knowledge of how materials are assembled and buildings are constructed, serve as a guide when fleshing out the form and substance of a building design. The form-generating capabilities of structural materials and systems—the skeletal frameworks of timber, steel, and concrete; the planar vocabulary of masonry bearing walls and concrete plates; and the volumetric possibilities of advanced diagrid systems—inform the potential of a design scheme for certain formal and expressive qualities.





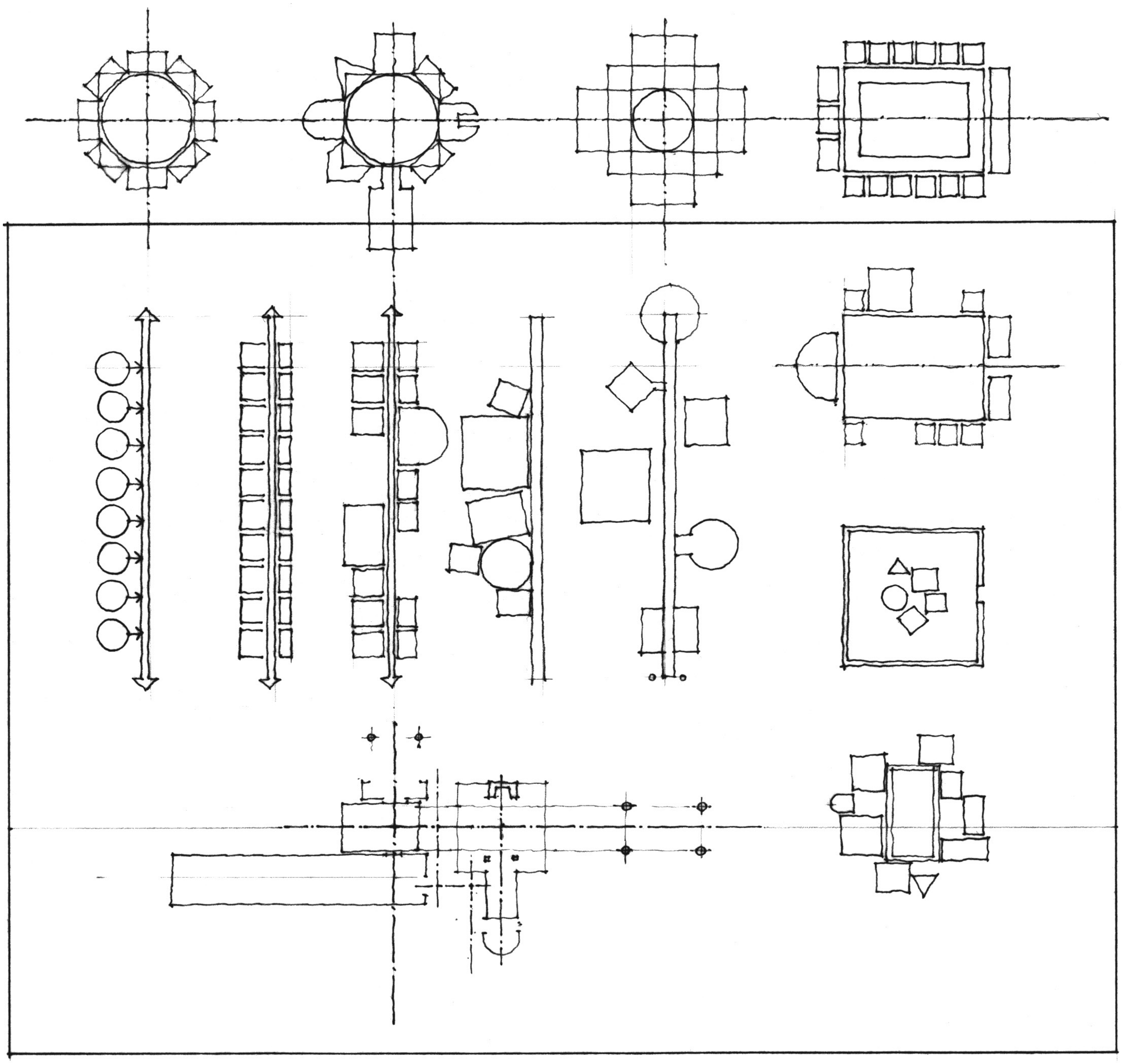


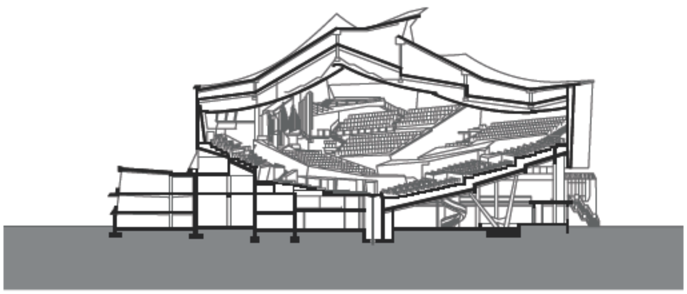
Systems Integration Matters

The successful layout of all systems of a building design, from the technical—structural, lighting, and environmental controls—to the spatial, requires that we continually think about how they are related and integrated in three dimensions. We can do this by overlaying plans and sections, or more holistically with paraline views.

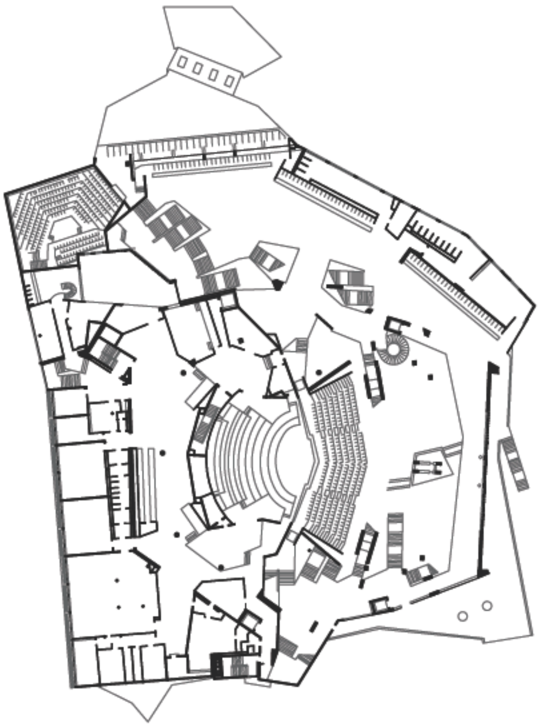
Formal Issues Matter

As we diagram the contextual, programmatic, structural, and constructional issues relevant to a design problem, we should be mindful that the formal qualities of the resulting drawings are natural by-products of the process. We cannot ignore what a diagram looks like nor what it might express in formal terms.

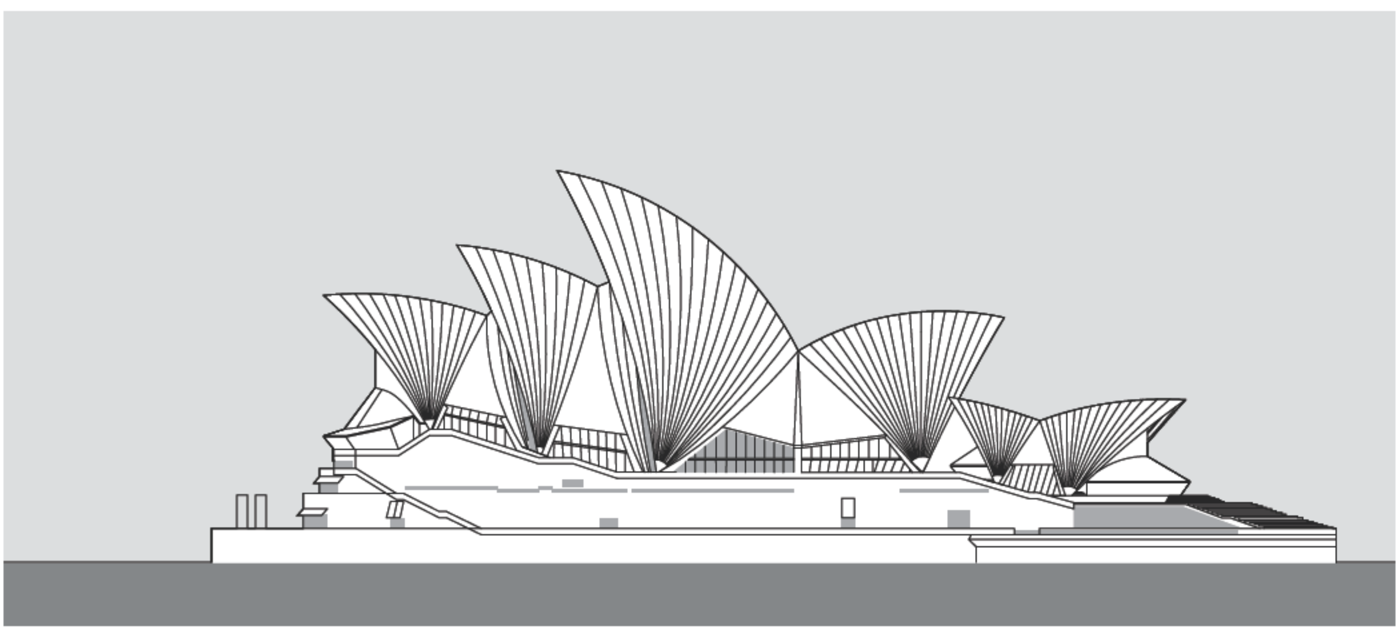




Just as our diagramming of relationships informs the composition of a design, our formal intentions should inform the diagramming process. There are even situations where specific formal qualities might be themselves primary drivers of the design process, as in the linear nature of transportation facilities, the verticality of high-rise structures, or the expansive nature of a suburban campus. Therefore, by overlaying contextual, programmatic, structural, and constructional possibilities with certain ordering principles, such as repetition, rhythm, or symmetry, we can make the adjustments necessary to clarify the essence of a design scheme.



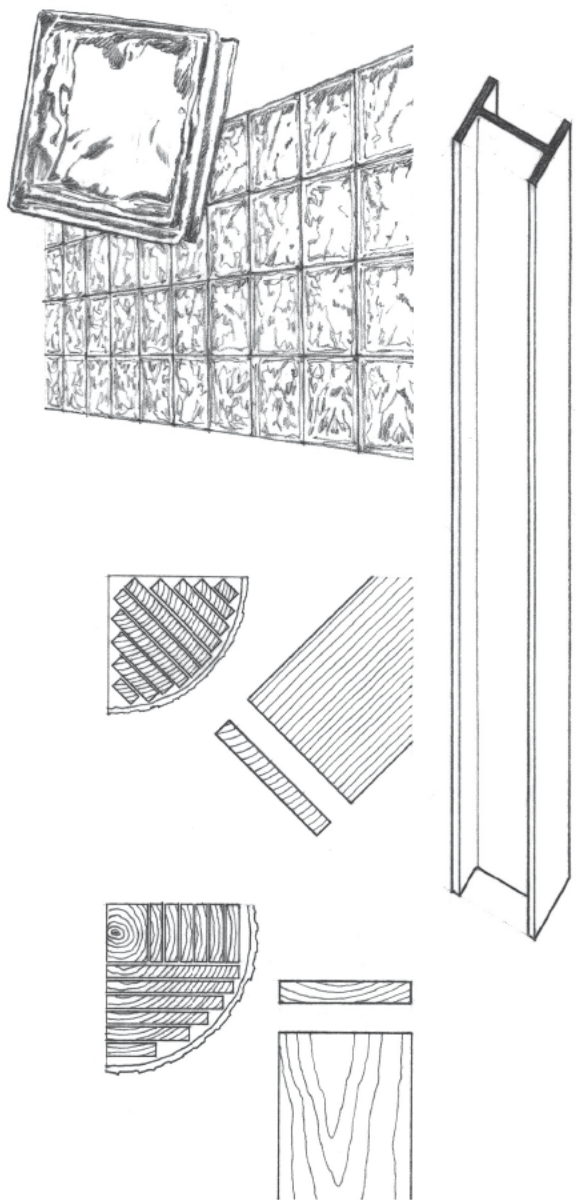
Philharmonic Hall, Berlin, Germany, 1960–1963, Hans Scharoun. An example of the Expressionist movement, this concert hall has an asymmetric structure with a tent-like concrete roof and a stage in the middle of terraced seating. Its external appearance is subordinate to the functional and acoustic requirements of the concert hall.



Sydney Opera House, 1973, Jørn Utzon. Iconic shell structures consist of prefabricated, cast-on-site concrete ribs.

9 Materials of Architecture:

Their Qualities, Characteristics, and Behaviors



How Do Materials Affect Design?

Material is an ever-present consideration of architecture. Material is even important at the outset of the design process. Architecture is a discipline that is reliant upon craft, which has two implications for design.

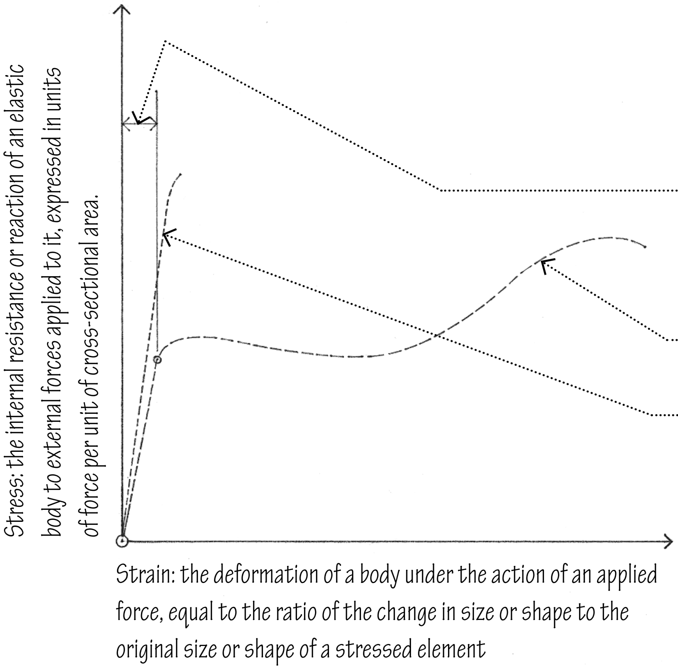
- The way materials behave as they are worked by a craftsperson.
- The way materials behave through the life of a building.

Every material has different properties that demand different techniques to be used in crafting with them. Some can be cut, others cannot. Some can be pulverized others cannot. Some can be melted others cannot. Furthermore, the means by which materials are divided, broken, or heated vary from one type to another. These techniques require an extensive knowledge of craft in order to properly manipulate a material for the purposes of making architecture. Although the architect may or may not be the craftsperson involved in constructing the building, he or she must have enough knowledge of them to propose designs that are feasible.

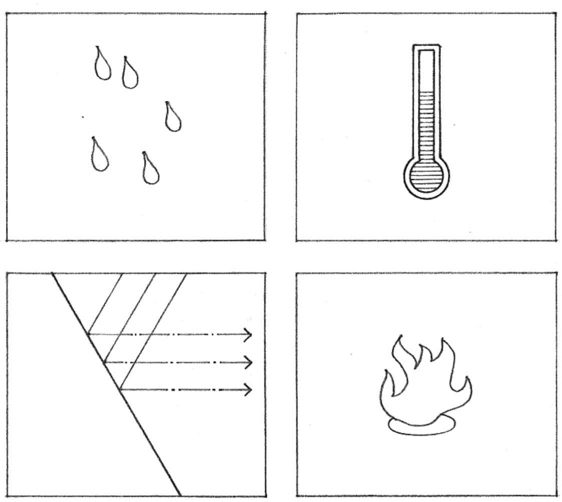
Furthermore, the architect must also be aware of material behavior once the building is complete. Just as different materials behave differently in the crafting process, they will also behave differently as they age or external forces act upon them. A good building will be a result of collaboration between architect, engineer, and builder to ensure that the materials used will adequately support a building throughout its lifetime. This chapter discusses the various materials of architecture. It provides information on common materials used in construction and the way they behave relative to other material options.

Building Materials

This section describes the major types of building materials, their physical properties, and their uses in building construction. The criteria for selecting and using a building material include those listed here:



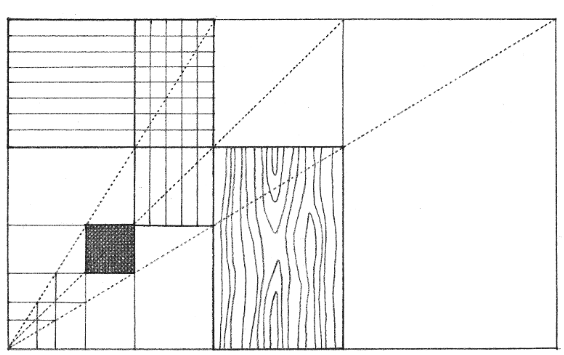
- Each material has distinct properties of strength, elasticity, and stiffness. The most effective structural materials are those that combine elasticity with stiffness.
- Elasticity is the ability of a material to deform under stress—bend, stretch, or compress—and return to its original shape when the applied stress is removed. Every material has its elastic limit beyond which it will permanently deform or break.
- Materials that undergo plastic deformation before actually breaking are termed ductile.
- Brittle materials, on the other hand, have low elastic limits and rupture under loads with little visible deformation. Because brittle materials have less reserve strength than ductile materials, they are not as suitable for structural purposes.
- Stiffness is a measure of the force required to push or pull a material to its elastic limit. A material's stiffness and the stiffness of its cross-sectional shape are important factors when considering the relationship between span and deflection under loading.



- The dimensional stability of a material as it responds to changes in temperature and moisture content affects the manner in which it is detailed and constructed to join with other materials.
- The resistance of a material to water and water vapor is an important consideration when it is exposed to weather or used in moist environments.
- The thermal conductivity or resistance of a material must be assessed when it is used in constructing the exterior envelope of a building.

- A material's transmission, reflection, or absorption of visible light and radiant heat should be evaluated when the material is used to finish the surfaces of a room.
- The density or hardness of a material determines its resistance to wear and abrasion, its durability in use, and the costs required to maintain it.

- The ability of a material to resist combustion, withstand exposure to fire, and not produce smoke and toxic gases must be evaluated before using it as a structural member or an interior finish.



- The color, texture, and scale of a material are obvious considerations in evaluating how it fits within the overall design scheme.
- Many building materials are manufactured in standard shapes and sizes. These stock dimensions, however, may vary slightly from one manufacturer to the next. They should be verified in the planning and design phases of a building so that unnecessary cutting or wasting of material can be minimized during construction.

The evaluation of building materials should extend beyond their functional, economic, and aesthetic aspects and include assessing the environmental consequences associated with their selection and use. This examination, called a life-cycle assessment, encompasses the extraction and processing of raw materials, the manufacturing, packaging, and transportation of the finished product to the point of use, maintaining the material in use, the possible recycling and reuse of the material, and its final disposal. This assessment process consists of three components: inputs, life-cycle inventory, and outputs.

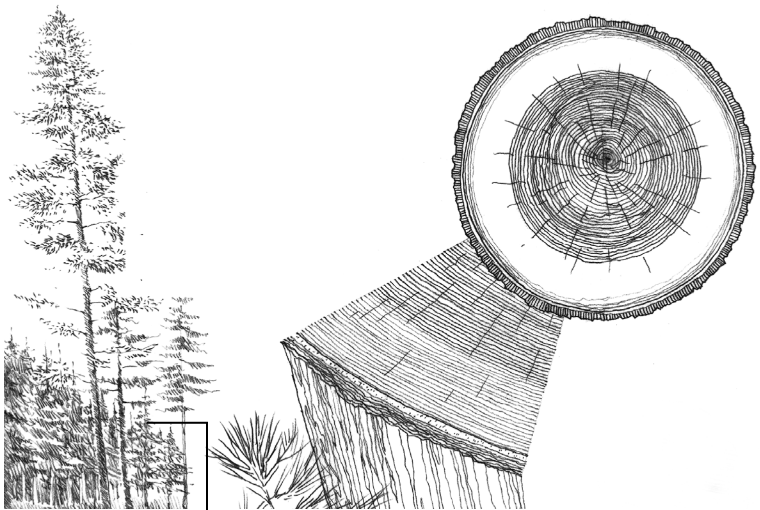
Embodied Energy in Building Materials

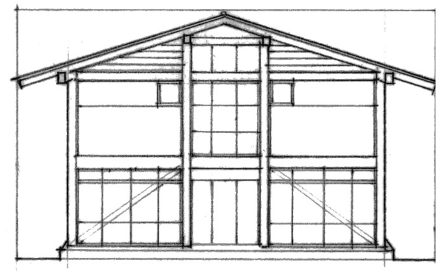
Material	Energy Content MJ / kg*	Embodied Carbon kg CO_2 / kg	Density kg / m^3
Aggregate	0.1	0.0048	2240
Concrete block	0.7	0.073	1450
Concrete	1.1	0.16	2400
Gypsum plaster	1.8	0.12	1750
Marble	2.0	0.12	2500
Plasterboard	6.8	0.38	800
Wood	10.0	0.72	480–720
Glue-laminated timber	12.0	0.87	—
Glass	15.0	0.85	2500
Plywood	15.0	1.07	540–700
Steel	20.1	1.37	7800
Mineral fiber roofing	37.0	2.70	1850
Copper	42.0	2.60	8600
Stainless steel	56.7	6.15	7850
Latex paint	59.0	2.12	—
Vinyl flooring	65.6	2.92	1200
Polyvinyl chloride	77.2	28.10	1380
Polyurethane insulation	88.6	3.48	30
Wool carpet	106.0	5.53	—
Aluminum	155.0	8.24	2700

*1 kJ / kg = 430 Btu / lb.

Adapted from the *Inventory of Carbon & Energy* prepared by Professor Geoff Hammond & Craig Jones, Sustainable Energy Research Team, Department of Mechanical Engineering, University of Bath, UK, 2008.

Embodied energy includes all of the energy expended during the life cycle of a material.





Inputs

- Raw materials
- Energy
- Water

Acquisition of Raw Materials

- What impact does the extraction, mining, or harvesting process have on health and the environment?
- Is the material renewable or nonrenewable?
- Nonrenewable resources include metals and other minerals.
- Renewable resources, such as timber, vary in their rate of renewal; their rate of harvest should not exceed their rate of growth.

Processing, Manufacturing, and Packaging

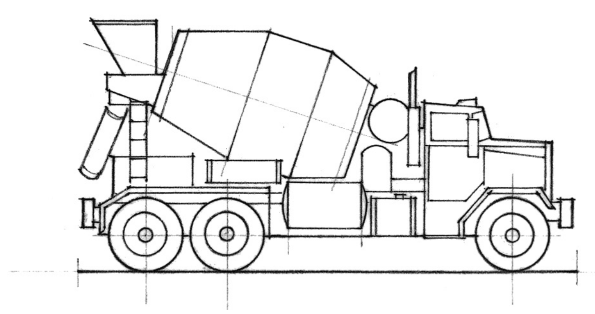
- How much energy and water is required to process, manufacture, and package the material or product?

Transportation and Distribution

- Is the material or product available regionally or locally, or does it have to be shipped a long distance?

Construction, Use, and Maintenance

- Does the material perform its intended function efficiently and effectively?
- How does the material affect the indoor air quality and energy consumption of a building?
- How durable is the material or product and how much maintenance is required for its upkeep?
- What is the material's useful life?



Life-Cycle Inventory

Evaluating the choice of a building material is a complex matter that cannot be reduced to a simple formula yielding a precise and valid answer with certainty. For example, using less of a material with a high energy content may be more effective in conserving energy and resources than using more of a lower-energy material. Using a higher-energy material that will last longer and require less maintenance, or one that can be recycled and reused, may be more compelling than using a lower-energy material.

- Reduce, reuse, and recycle best summarize the kinds of strategies that are effective in achieving the goal of sustainability.
- Reduce building size through more efficient layout and use of spaces.
- Reduce construction waste.
- Specify products that use raw materials more efficiently.
- Substitute plentiful resources for scarce resources.
- Reuse building materials from demolished buildings.
- Rehabilitate existing buildings for new uses.
- Recycle by making new products from old ones.

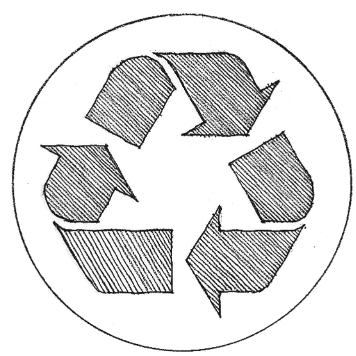
Disposal, Recycling, and Reuse

- Usable products

- How much waste and how many toxic by-products result from the manufacture and use of the material or product?

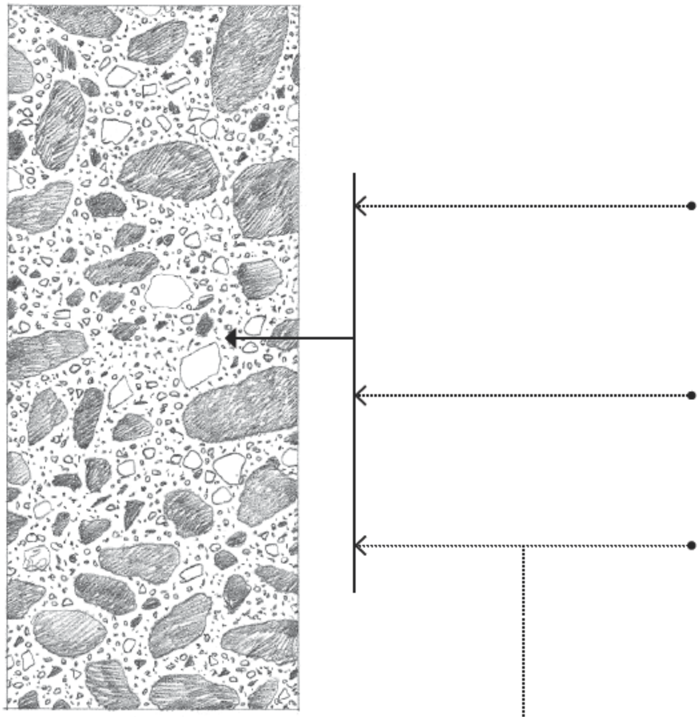
- Waterborne effluents
- Atmospheric emissions
- Solid wastes
- Other environmental releases

Outputs



Concrete

Concrete is made by mixing cement and various mineral aggregates with sufficient water to cause the cement to set and bind the entire mass. While concrete is inherently strong in compression, steel reinforcement is required to handle tensile and shear stresses. It is capable of being formed into almost any shape with a variety of surface finishes and textures. In addition, concrete structures are relatively low in cost and inherently fire resistant. Concrete's liabilities include its weight—150 pcf (2400 kg/m^3) for normal reinforced concrete—and the forming or molding process that is required before it can placed to set and cure.



Cement

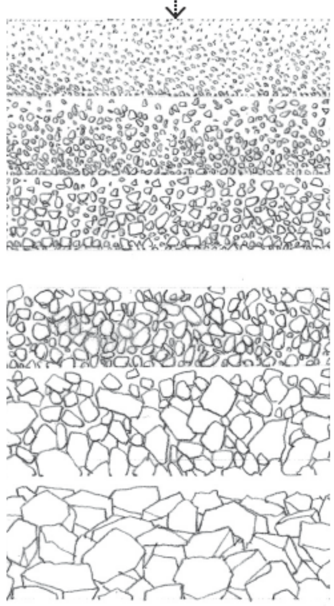
Portland cement is a hydraulic cement made by burning a mixture of clay and limestone in a rotary kiln and pulverizing the resulting clinker into a very fine powder.

Water

The water used in a concrete mix must be free of organic material, clay, and salts; a general criterion is that the water should be fit for drinking.

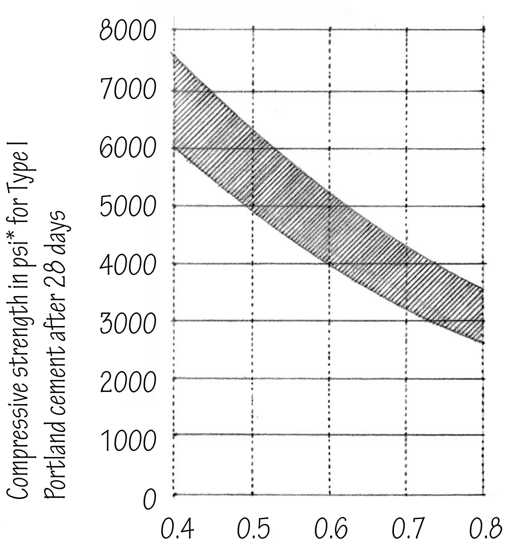
Aggregate

Aggregate refers to any of various inert mineral materials, such as sand and gravel, added to a cement paste to make concrete. Because aggregate represents from 60% to 80% of the concrete volume, its properties are important to the strength, weight, and fire resistance of the hardened concrete. Aggregate should be hard, dimensionally stable, and free of clay, silt, and organic matter that can prevent the cement matrix from binding the particles together.

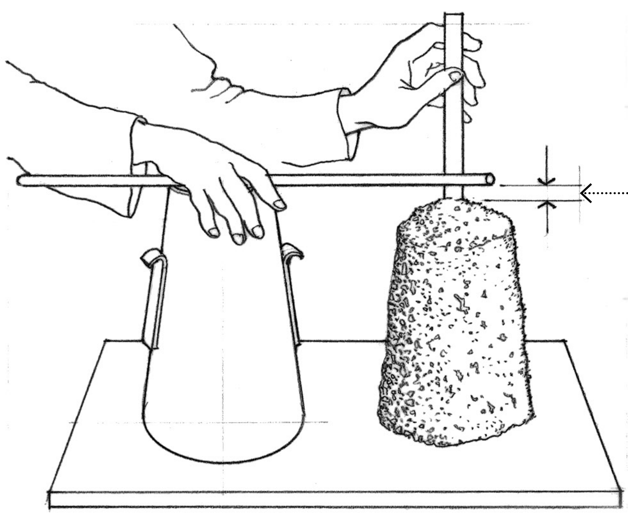


Water-Cement Ratio

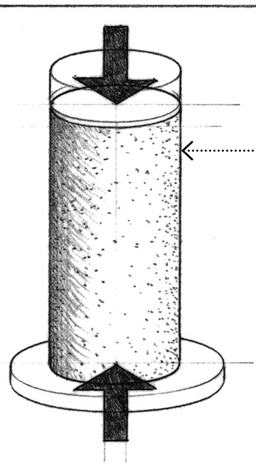
The water-cement ratio is the ratio of mixing water to cement in a unit volume of a concrete mix, expressed by weight as a decimal fraction or as gallons of water per sack of cement. The water-cement ratio controls the strength, durability, and watertightness of hardened concrete. According to Abram's law, formulated by D. A. Abrams in 1919 from experiments at the Lewis Institute in Chicago, the compressive strength of concrete is inversely proportional to the ratio of water to cement. If too much water is used, the concrete mix will be weak and porous after curing. If too little water is used, the mix will be dense but difficult to place and work. For most applications, the water-cement ratio should range from 0.45 to 0.60. Concrete is normally specified according to the compressive strength it will develop within 28 days after placement.



* 1 psi = 6.89 kPa



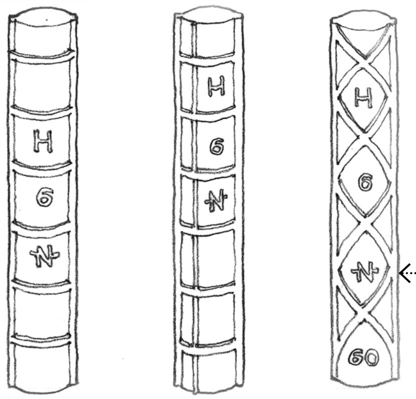
The slump test is a method for determining the consistency and workability of freshly mixed concrete by measuring the slump of a test specimen, expressed as the vertical settling, in inches, of a specimen after it has been placed in a slump cone and tamped in a prescribed manner, and the cone is lifted.



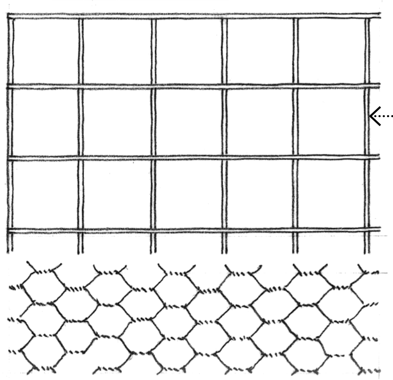
Compression test for determining the compressive strength of a concrete batch uses a hydraulic press to measure the maximum load a test cylinder 6 in. (150) in diameter and 12 in. (305) high can support in axial compression before fracturing.

Steel Reinforcement

Because concrete is relatively weak in tension, reinforcement consisting of steel bars, strands, or wires is required to absorb tensile, shearing, and sometimes the compressive stresses in a concrete member or structure. Steel reinforcement is also required to tie vertical and horizontal elements, reinforce the edges around openings, minimize shrinkage cracking, and control thermal expansion and contraction. All reinforcement should be designed by a qualified structural engineer.

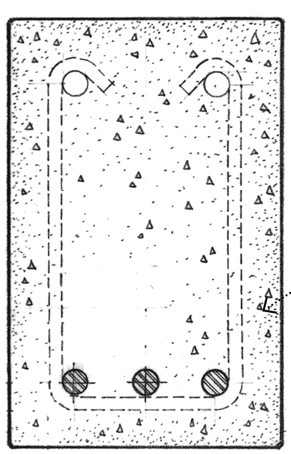


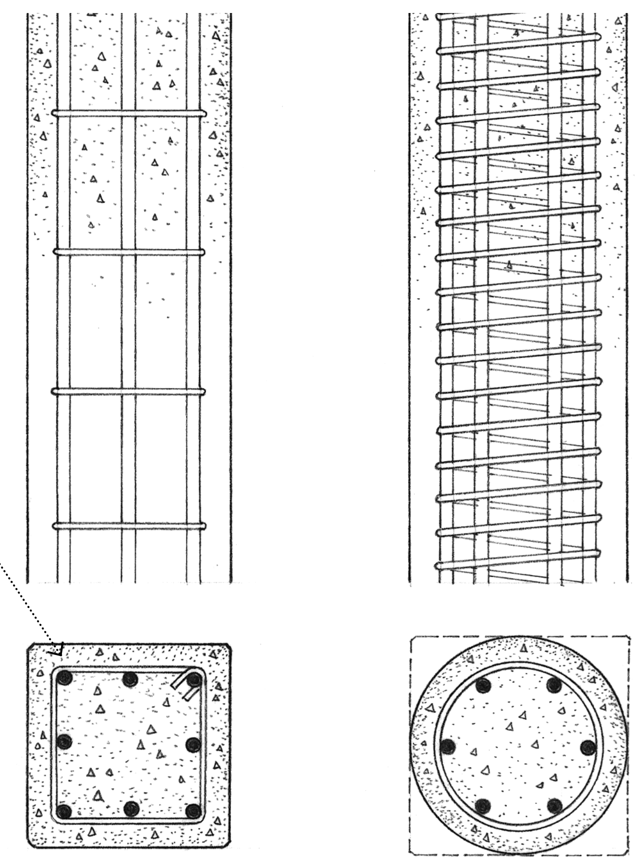
- Reinforcing bars are steel sections hot-rolled with ribs or other deformations for better mechanical bonding to concrete.



- Welded wire fabric consists of a grid of steel wires or bars welded together at all points of intersection. The fabric is typically used to provide temperature reinforcement for slabs but the heavier gauges can also be used to reinforce concrete walls.

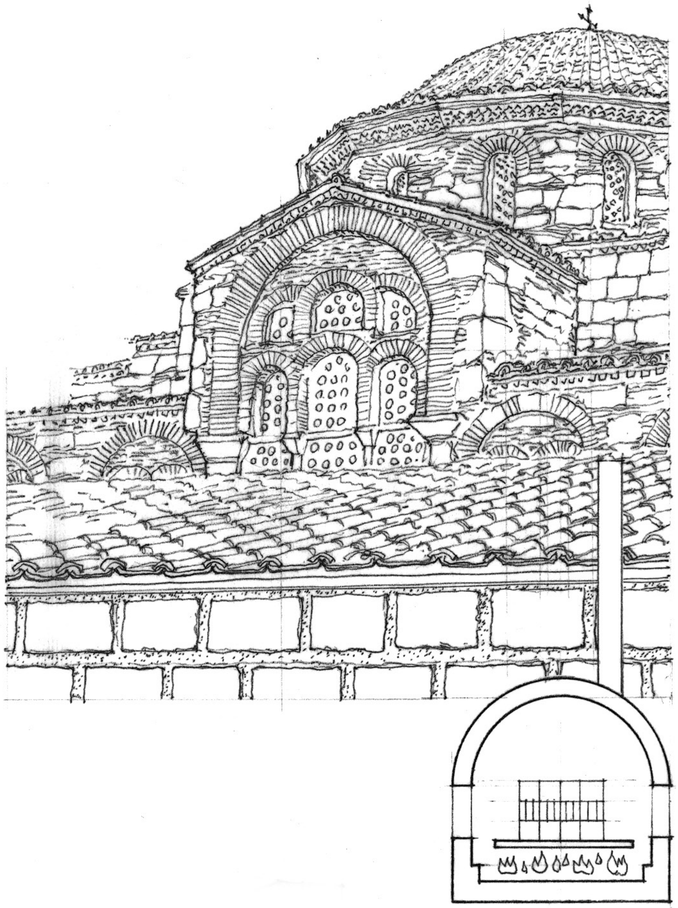
- Reinforcing steel must be protected by the surrounding concrete against corrosion and fire.





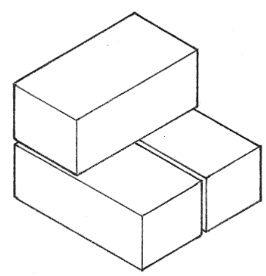
Masonry

Masonry refers to building with units of various natural or manufactured products, such as brick, stone, or concrete block, usually with the use of mortar as a bonding agent. The modular aspect (i.e., uniform sizes and proportional relationships) of unit masonry distinguishes it from most of the other building materials discussed in this chapter. Because unit masonry is structurally most effective in compression, the masonry units should be laid up in such a way that the entire masonry mass acts as an entity.

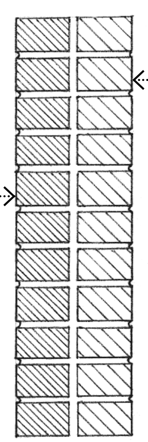


Brick

Brick is a masonry unit of clay, formed into a rectangular prism while plastic and hardened by firing in a kiln or drying in the sun.



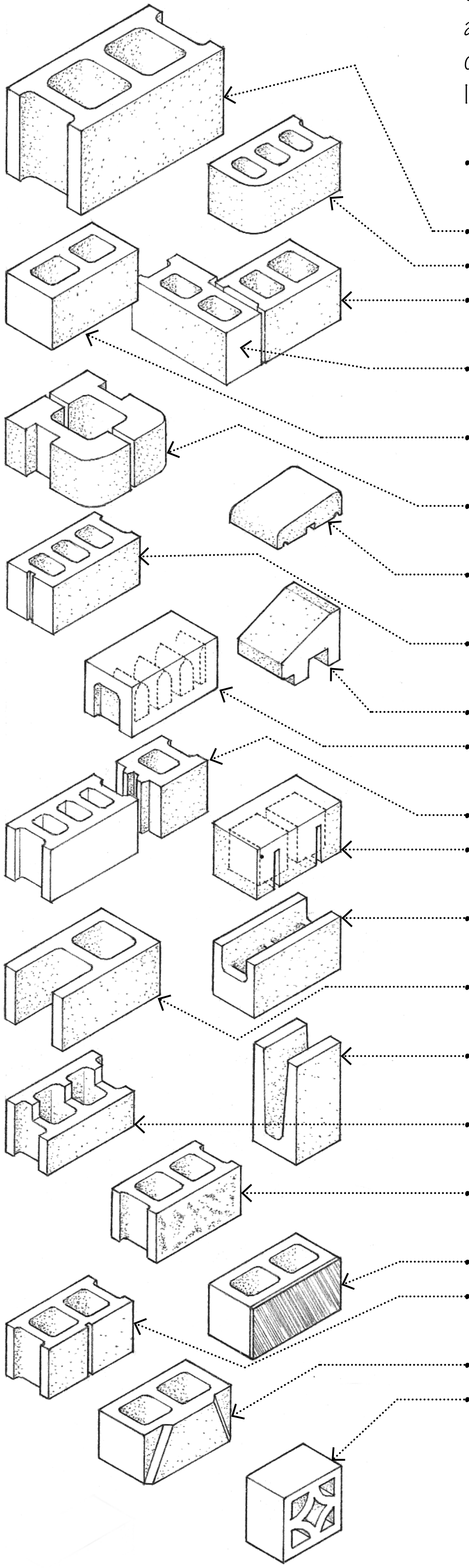
- Face brick is made of special clays for facing a wall, often treated to produce the desired color and surface texture.



- Common brick, also called building brick, is made for general building purposes and not specially treated for color and texture.

Concrete Masonry

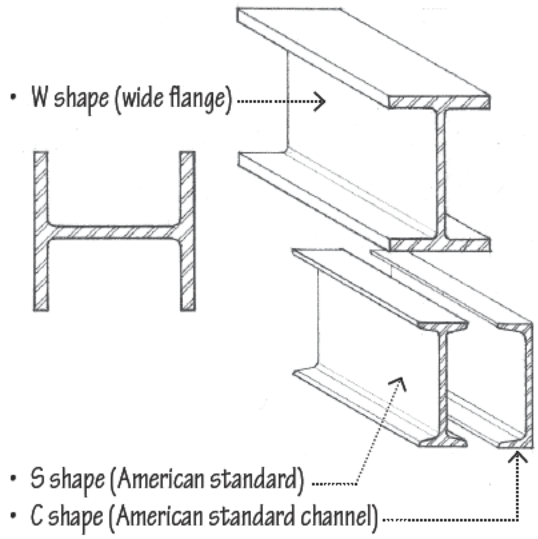
Concrete masonry units (CMU) are precast of Portland cement, fine aggregate, and water, molded into various shapes to satisfy various construction conditions. The availability of these types varies with locality and manufacturer.

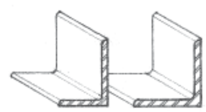


- Concrete block, often incorrectly referred to as cement block, is a hollow concrete masonry unit.
- Stretcher blocks have two or three cores.
- Bullnose blocks have one or more rounded exterior corners.
- Corner blocks have a solid end face for use in constructing the end or corner of a wall.
- Corner-return blocks are used at the corners of walls to maintain horizontal coursing with the appearance of full-and half-length units.
- Double-corner blocks have solid faces at both ends and are used in constructing a masonry pier.
- Pilaster blocks are used in constructing a plain or reinforced masonry pilaster.
- Coping blocks are used in constructing the top or finishing course of a masonry wall.
- Sash or jamb blocks have an end slot or rabbet to receive the jamb of a door or window frame.
- Sill blocks have a wash to shed rainwater from a sill.
- Cap blocks have a solid top for use as a bearing surface in the finishing course of a foundation wall.
- Control-joint blocks are used in constructing a vertical control joint.
- Sound-absorbing masonry units have a solid top and a slotted face shell, and sometimes a fibrous filler, for increased sound absorption.
- Bond-beam blocks have a depressed section in which reinforcing steel can be placed for embedment in grout.
- Open-end blocks have one end open in which vertical steel reinforcement can be placed for embedment in grout.
- Lintel blocks have a U-shaped section in which reinforcing steel can be placed for embedment in grout.
- Header blocks have a portion of one face shell removed to receive headers in a bonded masonry wall.
- Split-face blocks are split lengthwise by a machine after curing to produce a rough, fractured face texture.
- Faced blocks have a special ceramic, glazed, or polished face.
- Scored blocks have one or more vertical grooves that simulate raked joints.
- Shadow blocks have a face shell with a pattern of beveled recesses.
- Screen blocks, used especially in tropical architecture, have a decorative pattern of transverse openings for admitting air and excluding sunlight.

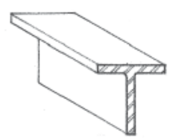
Steel

Steel refers to any of various iron-based alloys having a carbon content less than that of cast iron and more than that of wrought iron, and having qualities of strength, hardness, and elasticity varying according to composition and heat treatment. Steel is used for light and heavy structural framing, as well as a wide range of building products such as windows, doors, hardware, and fastenings. As a structural material, steel combines high strength and stiffness with elasticity. Measured in terms of weight to volume, it is probably the strongest low-cost material available. Although classified as an incombustible material, steel becomes ductile and loses its strength when subject to temperatures over 1000°F (520°C). When used in buildings requiring fire-resistive construction, structural steel must be coated, covered, or enclosed with fire-resistant materials. Because it is normally subject to corrosion, steel must be painted, galvanized, or chemically treated for protection against oxidation.

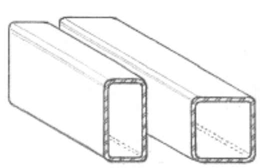




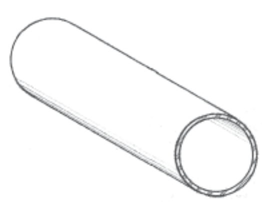
• L shapes (equal and unequal leg angles)



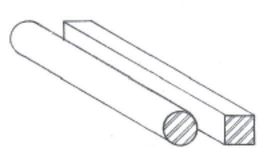
• WT shape (structural tee cut from W shape)



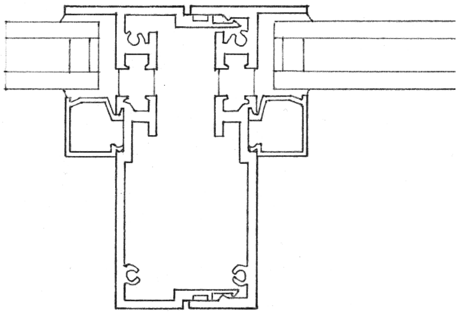
• Structural tubing (square or rectangular)

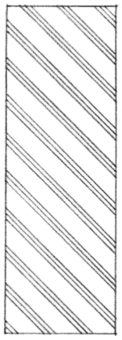


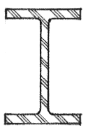
• Structural tubing (circular pipe)

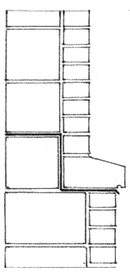


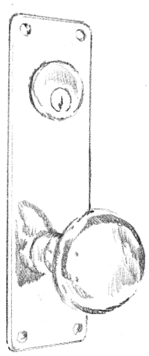
• Bars (square, round, and flat)











Nonferrous Metals

Nonferrous metals contain no iron. Aluminum, copper, and lead are nonferrous metals commonly used in building construction.
Aluminum is a ductile, malleable, silver-white metallic element that is used in forming many hard, light alloys. Its natural resistance to corrosion is the result of the transparent film of oxide that forms on its surface; this oxide coating can be thickened to increase corrosion resistance by an electrical and chemical process known as anodizing. During the anodizing process, the naturally light, reflective surface of aluminum can be dyed a number of warm, bright colors. Care must be taken to insulate aluminum from contact with other metals to prevent galvanic action. It should also be isolated from alkaline materials such as wet concrete, mortar, and plaster.

Aluminum is widely used in extruded and sheet forms for secondary building elements such as windows, doors, roofing, flashing, trim, and hardware. For use in structural framing, high-strength aluminum alloys are available in shapes similar to those of structural steel. Aluminum sections may be welded, bonded with adhesives, or mechanically fastened.

Copper is a ductile, malleable metallic element that is widely used for electrical wiring, water piping, and in the manufacture of alloys, as bronze and brass. Its color and resistance to corrosion also make it an excellent roofing and flashing material. However, copper will corrode aluminum, steel, stainless steel, and zinc. It should be fastened, attached, or supported only with copper or carefully selected brass fittings. Contact with red cedar in the presence of moisture will cause premature deterioration of the copper.

Brass refers to any of various alloys consisting essentially of copper and zinc, used for windows, railings, trim, and finish hardware. Alloys that are brass by definition may have names that include the word bronze, as architectural bronze.

Lead is a heavy, soft, malleable, bluish-gray metallic element used for flashing, sound isolation, and radiation shielding. Although lead is the heaviest of the common metals, its pliability makes it desirable for application over uneven surfaces. Lead dust and vapors are toxic.

- Gold, platinum — **Most noble**
- Titanium — Cathode (+)
- Silver
- Stainless steel
- Bronze
- Copper
- Brass
- Nickel
- Tin
- Lead
- Cast iron
- Mild steel
- Aluminum, 2024 T4
- Cadmium
- Aluminum, 1100
- Zinc — Anode (–)
- Magnesium — **Least noble**

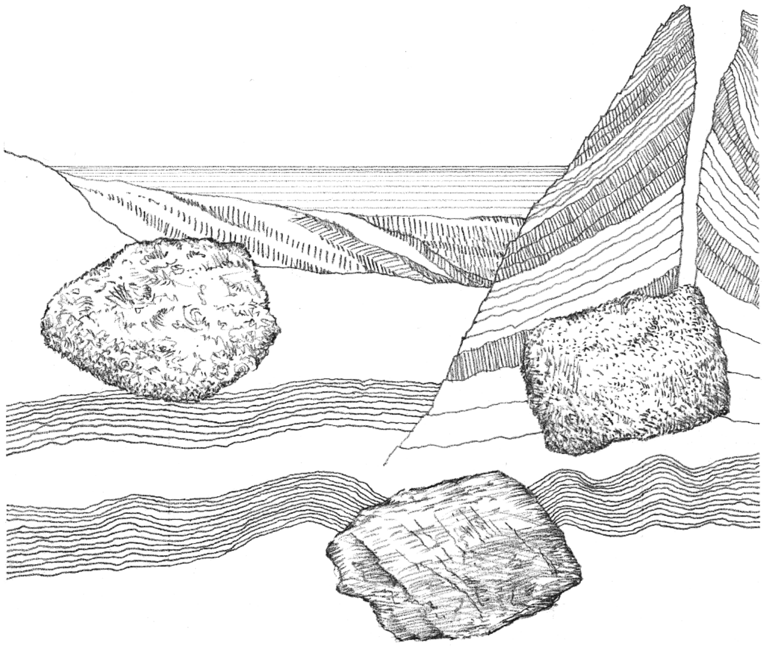
Current flows from positive to negative.

Galvanic Series

- The galvanic series lists metals in order from most noble to least noble.
- Noble metals, such as gold and silver, resist oxidation when heated in air and solution by inorganic acids.
- The metal that is lower in the list is sacrificial and corrodes when enough moisture is present for electric current to flow.
- The farther apart two metals are on the list, the more susceptible the least noble one is to corrosive deterioration.

Galvanic Action

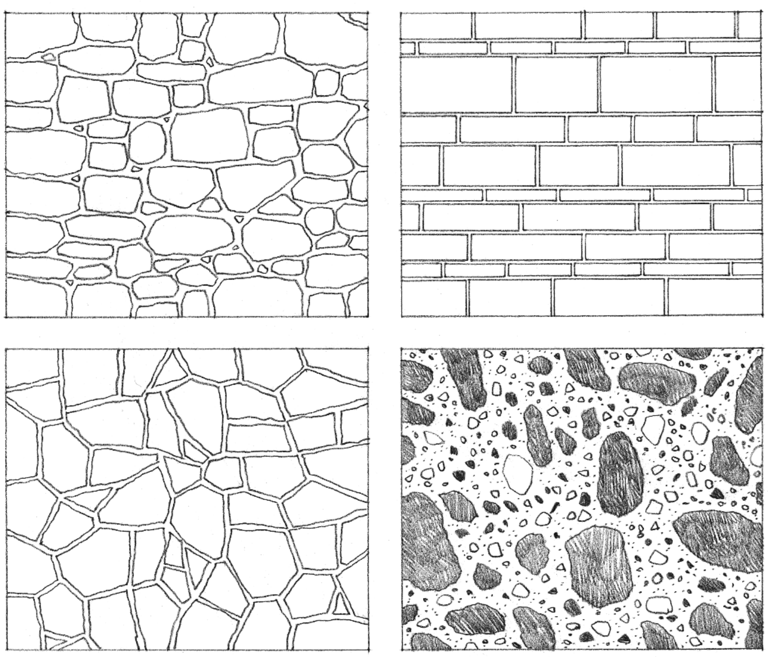
Galvanic action can occur between two dissimilar metals when enough moisture is present for electric current to flow. This electric current will tend to corrode one metal while plating the other. The severity of the galvanic action depends on how far apart the two metals are on the galvanic series table.



Stone

Stone is an aggregate or combination of minerals, each of which is composed of inorganic chemical substances. To qualify as a construction material, stone should have the following qualities:

- Strength: Most types of stone have more than adequate compressive strength. The shear strength of stone, however, is usually about 1/10 of its compressive strength.
- Hardness: Hardness is important when stone is used for flooring, paving, and stair treads.
- Durability: Resistance to the weathering effects of rain, wind, heat, and frost action is necessary for exterior stonework.
- Workability: A stone's hardness and grain texture must allow it to be quarried, cut, and shaped.
- Density: A stone's porosity affects its ability to withstand frost action and staining.
- Appearance: Appearance factors include color, grain, and texture.



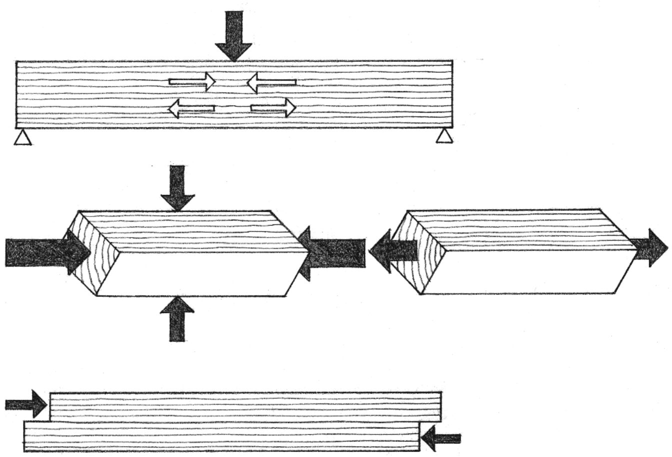
As a load-bearing wall material, stone is similar to modular unit masonry. Although stone masonry is not necessarily uniform in size, it is laid up with mortar and used in compression. Almost all stone is adversely affected by sudden changes in temperature and should not be used where a high degree of fire resistance is required.

- Stone is used in construction in the following forms:
- Rubble consists of rough fragments of broken stone that have at least one good face for exposure in a wall.
- Dimension stone is quarried and squared stone 2 ft. (610mm) or more in length and width and of specified thickness, used commonly for wall panels, cornices, copings, lintels, and flooring.
- Flagstone refers to flat stone slabs used for flooring and horizontal surfacing.
- Crushed stone is used as aggregate in concrete products.

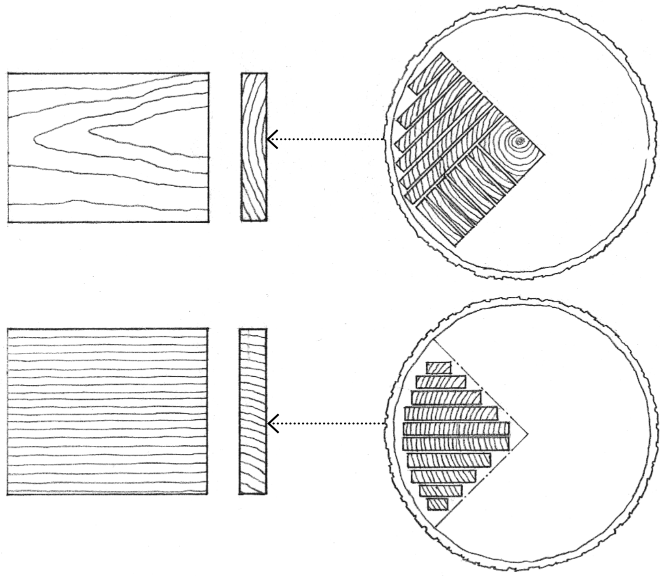
Wood

As a construction material, wood is strong, durable, light in weight, and easy to work. In addition, it offers natural beauty and warmth to sight and touch. Although it has become necessary to employ conservation measures to ensure a continued supply, wood is still used on construction in many and varied forms.

There are two major classes of wood—softwood and hardwood. These terms are not descriptive of the actual hardness, softness, or strength of a wood. Softwood is the wood from any of various predominantly evergreen, cone-bearing trees, as pine, fir, hemlock, and spruce, used for general construction. Hardwood is the wood from a broad-leaved flowering tree, as cherry, maple, or oak, typically used for flooring, paneling, furniture, and interior trim.

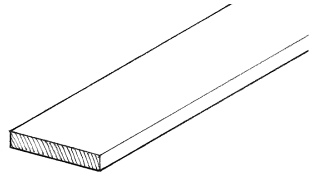


The manner in which a tree grows affects its strength, its susceptibility to expansion and contraction, and its effectiveness as an insulator. Grain direction is the major determining factor in the use of wood as a structural material. Tensile and compressive forces are best handled by wood in a direction parallel to the grain. Typically, a given piece of wood will withstand $^1/_3$ more force in compression than in tension parallel to its grain. The allowable compressive force perpendicular to its grain is only about $^1/_5$ to $^1/_2$ of the allowable compressive force parallel to the grain. Tensile forces perpendicular to the grain will cause the wood to split. The shear strength of wood is greater across its grain than parallel to the grain. It is, therefore, more susceptible to horizontal shear than to vertical shear.

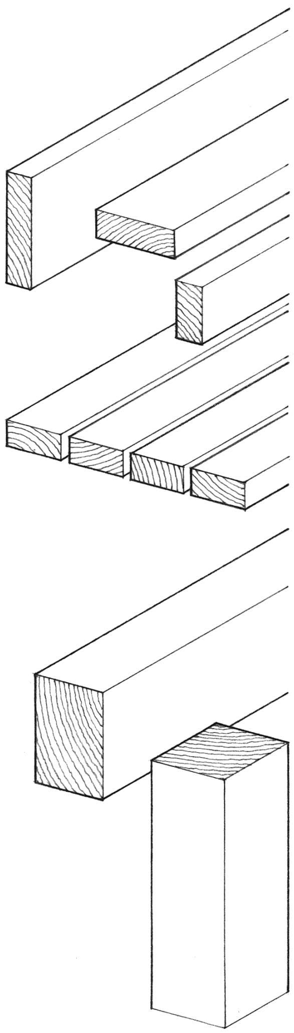


Tree growth also affects how pieces of sawn wood may be joined to form the structure and enclosure of a building.

Lumber

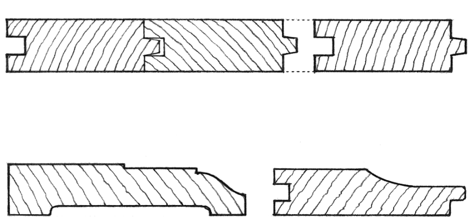


Because of the diversity of its applications and its use for remanufacturing purposes, hardwood is graded according to the amount of clear, usable lumber in a piece that may be cut into smaller pieces of a certain grade and size. Softwood is classified in the following manner.



- Boards: less than 2 in. thick and 2 in. or more wide, graded for appearance rather than strength
- Dimension lumber: from 2 in. to 4 in. thick and 2 in. or more wide, graded for strength rather than appearance
- Structural lumber: dimension lumber and timbers graded either by visual inspection or mechanically on the basis of strength and intended use
- Timbers: 5 in. or more in the least dimension, graded for strength and serviceability

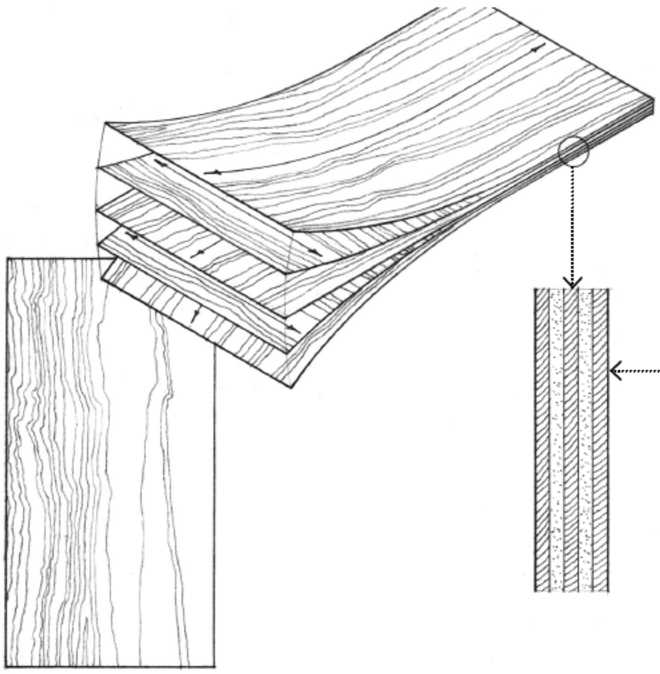
- Yard lumber: softwood lumber intended for general building purposes, including boards, dimension lumber, and timbers



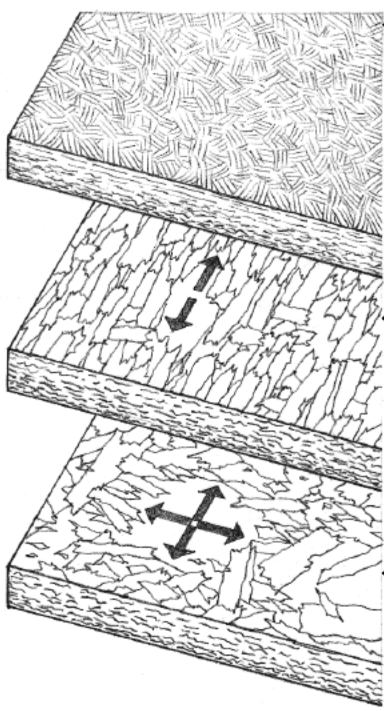
- Factory and shop lumber: sawn or selected primarily for further manufacture into doors, windows, and millwork, and graded according to the amount of usable wood that will produce cuttings of a specified size and quality

Wood Panel Products

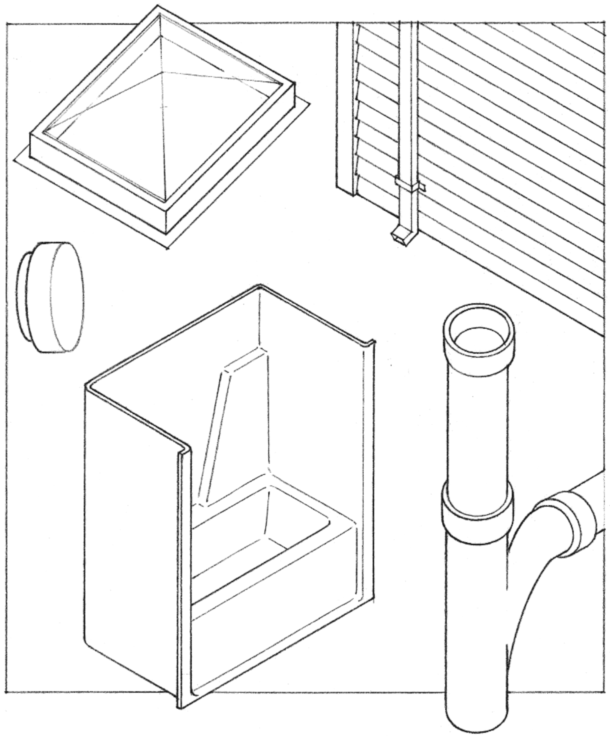
Wood panel products are less susceptible to shrinking or swelling, require less labor to install, and make more efficient use of wood resources than solid wood products. The following are the major types of wood panel products:



- Plywood is made by bonding veneers together under heat and pressure, usually with the grain of adjacent plies at right angles to each other and symmetrical about the center ply.



- Particleboard is a nonveneered wood panel product made by bonding small wood particles under heat and pressure, commonly used as a core material for decorative panels and cabinetwork, and as underlayment for floors.
- Oriented strandboard (OSB) is a nonveneered wood panel product commonly used for sheathing and as subflooring, made by bonding layers of long, thin wood strands under heat and pressure using a waterproof adhesive. The surface strands are aligned parallel to the long axis of the panel, making the panel stronger along its length.
- Waferboard is a nonveneered panel product composed of large, thin wood flakes bonded under heat and pressure with a waterproof adhesive. The planes of the wafers are generally oriented parallel to the plane of the panel but their grain directions are random, making the panel approximately equal in strength and stiffness in all directions in the plane of the panel.



Plastics

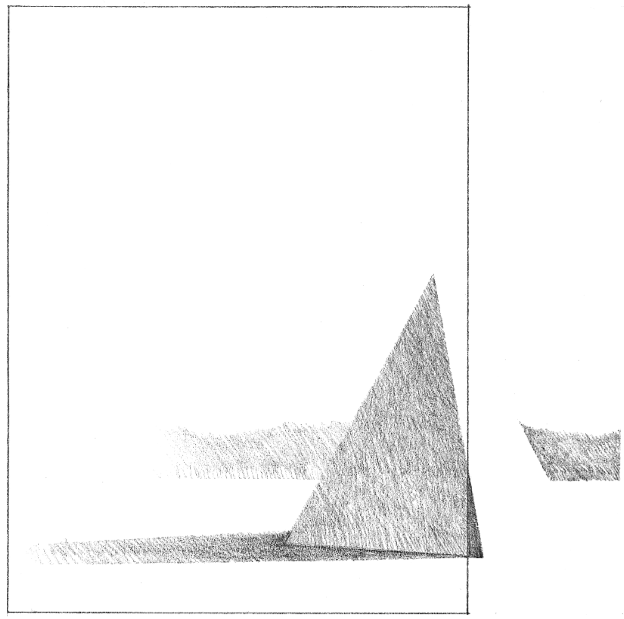
Plastics are any of the numerous synthetic or natural organic materials that are mostly thermoplastic or thermosetting polymers of high molecular weight and that can be molded, extruded, or drawn into objects, films, or filaments. As a class, plastics are tough, resilient, lightweight, and resistant to corrosion and moisture. Many plastics also emit gases harmful to the respiratory system and release toxic fumes when burned.

While there are many types of plastics with a wide range of characteristics, they can be divided into two basic categories:

- Thermosetting plastics go through a pliable stage, but once they are set or cured, they become permanently rigid and cannot be softened again by reheating.
- Thermoplastics are capable of softening or fusing when heated without a change in any inherent properties, and of hardening again when cooled.

In the table below are listed the plastics that are commonly used in construction and their primary uses.

Thermosetting Plastics	Uses
Epoxies	Adhesives and surface coatings
Melamines	High-pressure laminates, molded products, adhesives, coatings
Phenolics	Electrical parts, laminates, foam insulation, adhesives, coatings
Polyesters	Fiberglass-reinforced plastics, skylights, plumbing fixtures, films
Polyurethanes	Foam insulation, sealants, adhesives, coatings
Silicones	Waterproofing, lubricants, adhesives, synthetic rubber
Thermoplastics	**Uses**
Acrylonitrile-butadiene-styrene	Pipe and pipe fittings, door hardware
Acrylics	Glazing, adhesives, caulking, latex paints
Cellulosics	Pipe and pipe fittings, adhesives
Nylons	Synthetic fibers and filaments, hardware
Polycarbonates	Safety glazing, lighting fixtures, hardware
Polyethylene	Dampproofing, vapor retarder, electrical insulation
Polypropylene	Pipe fittings, electrical insulation, carpeting fibers
Polystyrene	Lighting fixtures, foam insulation
Vinyls	Flooring, siding, gutters, window frames, insulation, piping

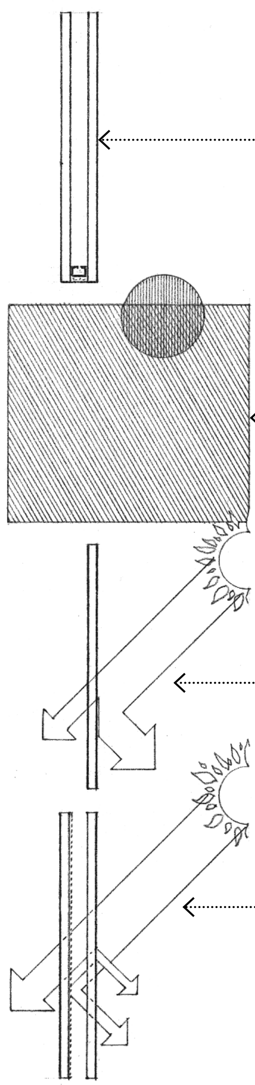


Glass

Glass is a hard, brittle, chemically inert substance produced by fusing silica together with a flux and a stabilizer into a mass that cools to a rigid condition without crystallization. It is used in building construction in various forms. Foamed or cellular glass is used as rigid, vapor proof thermal insulation. Glass fibers are used in textiles and for material reinforcement. In spun form, glass fibers form glass wool, which is used for acoustical and thermal insulation. Glass block is used to control light transmission, glare, and solar radiation. Glass, however, is used most commonly to glaze the window, sash, and skylight openings of buildings.

The three major types of flat glass are the following:

- Sheet glass is fabricated by drawing the molten glass from a furnace (drawn glass), or by forming a cylinder, dividing it lengthwise, and flattening it (cylinder glass). The fire-polished surfaces are not perfectly parallel, resulting in some distortion of vision. To minimize this distortion, glass should be glazed with the wave distortion running horizontally.
- Plate glass is formed by rolling molten glass into a plate that is subsequently ground and polished after cooling. Plate glass provides virtually clear, undistorted vision.
- Float glass is manufactured by pouring molten glass onto a surface of molten tin and allowing it to cool slowly. The resulting flat, parallel surfaces minimize distortion and eliminate the need for grinding and polishing. Float glass is the successor to plate glass and accounts for the majority of flat-glass production.



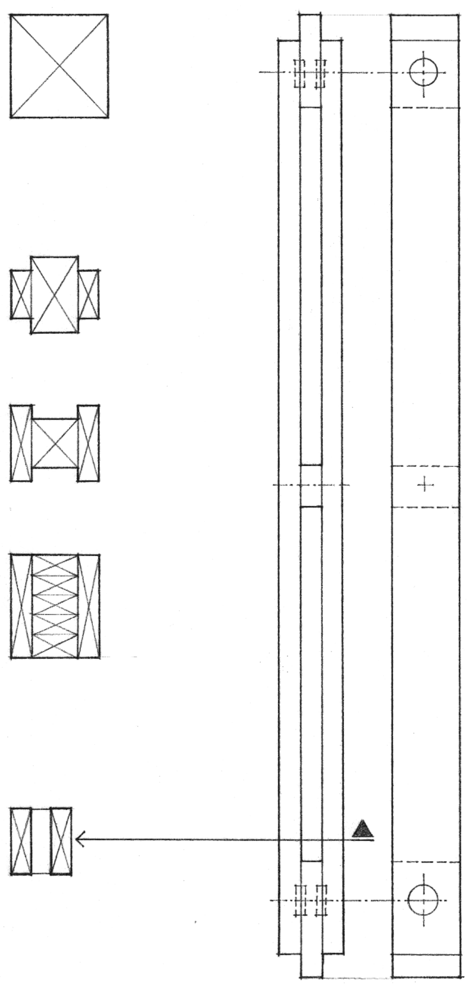
- Insulating glass is a glass unit consisting of two or more sheets of glass separated by a hermetically sealed air space to provide thermal insulation and restrict condensation; glass edge units have a $^{3}/_{16}$ in. air space; metal edge units have a $^{1}/_{4}$ in. or $^{1}/_{2}$ in. air space.

- Tinted or heat-absorbing glass has a chemical admixture to absorb a portion of the radiant heat and visible light that strike it. Iron oxide gives the glass a pale blue-green tint; cobalt oxide and nickel impart a grayish tint; selenium infuses it with a bronze tint.
- Reflective glass has a thin, translucent metallic coating to reflect a portion of the light and radiant heat that strike it. The coating may be applied to one surface of single glazing, in between the plies of laminated glass, or to the exterior or interior surfaces of insulating glass.

- Low-emissivity (low-e) glass transmits visible light while selectively reflecting the longer wavelengths of radiant heat, produced by depositing a low-e coating either on the glass itself or over a transparent plastic film suspended in the sealed air space of insulating glass.

10 Methods of Construction

What Are the Implications of Construction Methods on Architectural Design?



The act of making is intrinsic to design. The design process relies on making to generate ideas and discover new possibilities for a project. This act of making can be in the craft of a drawing or a model. This sensibility ties building construction to architectural design in several ways.

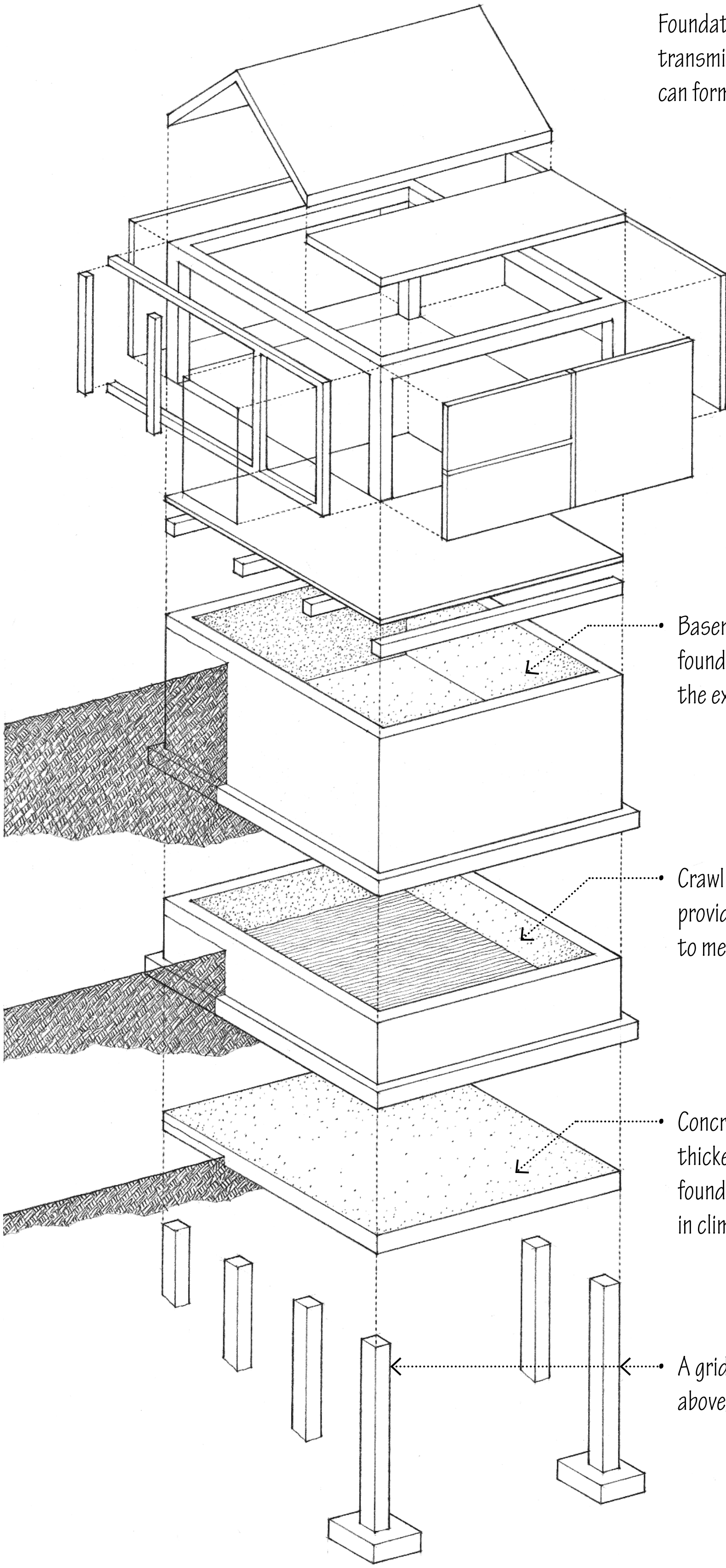
- The architect must have enough knowledge of construction to understand the materials and techniques that will most benefit the design.
- The architect is also responsible for designing the details and connections between elements.

In detailing a design, there are many opportunities to reinforce ideas at a minute scale. It is through the design of details and a knowledge of construction techniques that the architect can choose to reveal—or not—the intricacy of assemblies in the way the parts of the building come together. These details have the potential to influence the experience of an occupant as they provide opportunities to create an opening for light, a handle to grasp, or expose a complex connection.

This chapter discusses various construction methods, their advantages and disadvantages, and their application to design. The methods outlined here present a brief overview of possibilities available to an architect in order to realize design ideas. These methods begin at the ground with methods for foundation construction and move up to roof construction.

Foundations

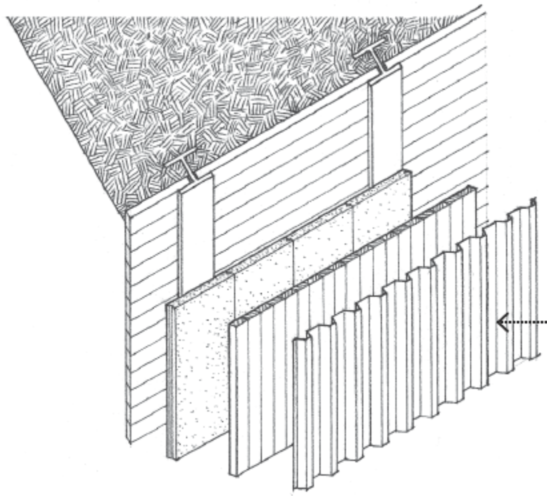
Foundations use a combination of bearing walls, columns, and piers to transmit building loads directly to the earth. These structural elements can form various types of substructures:



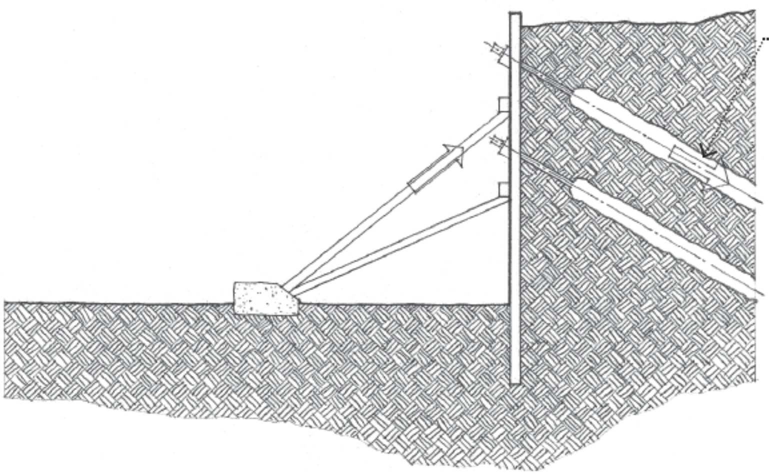
- Basements wholly or partly below grade require a continuous foundation wall to hold back the surrounding earth and support the exterior walls and columns of the superstructure above.
- Crawl spaces enclosed by a continuous foundation wall or piers provide space under a first floor for the integration of and access to mechanical, electrical, and plumbing installations.
- Concrete slabs-on-grade supported directly by the earth and thickened to carry wall and column loads form an economical foundation and floor system for one- and two story structures in climates where little or no ground frost occurs.
- A grid of independent piers or poles can elevate the superstructure above the surface of the ground.

Excavation Support Systems

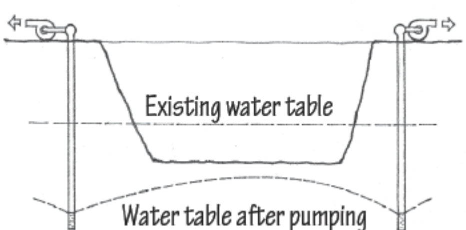
When the building site is sufficiently large that the sides of an excavation can be bench terraced or sloped at an angle less than the angle of repose for the soil, no supporting structure is necessary. When the sides of a deep excavation exceeds the angle of repose for the soil, however, the earth must be temporarily braced or shored until the permanent construction is in place.

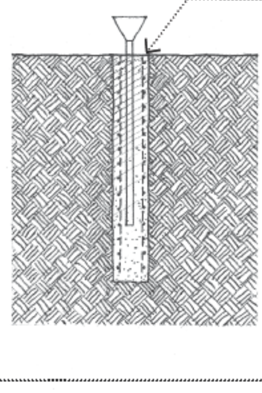


- Sheet piling consists of timber, steel, or precast concrete planks driven vertically side by side to retain earth and prevent water from seeping into an excavation. Steel and precast concrete sheet piling may be left in place as part of the substructure of a building.



- Tiebacks secured to rock or soil anchors may be used if crossbracing or rakers would interfere with the excavation or construction operation. The tiebacks consist of steel cables or tendons that are inserted into holes predrilled through the sheet piling and into rock or a suitable stratum of soil, grouted under pressure to anchor them to the rock or soil, and posttensioned with a hydraulic jack. The tiebacks are then secured to continuous, horizontal steel wales to maintain the tension.



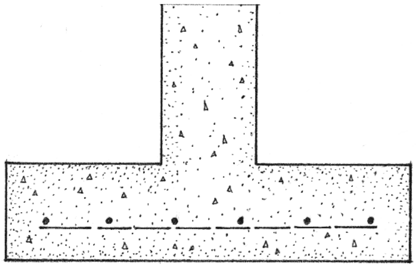


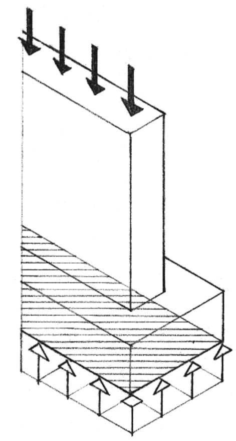
- A slurry wall is a concrete wall cast in a trench to serve as sheeting and often as a permanent foundation wall. It is constructed by excavating a trench in short lengths, filling it with a slurry of bentonite and water to prevent the sidewalls from collapsing, setting reinforcement, and placing concrete in the trench with a tremie to displace the slurry.

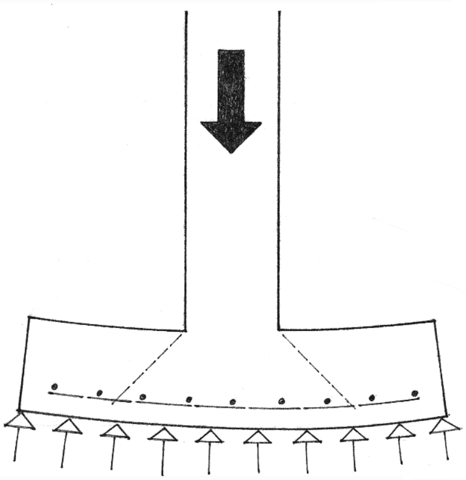
- Dewatering refers to the process of lowering a water table or preventing an excavation from filling with groundwater. It is accomplished by driving perforated tubes called wellpoints into the ground to collect water from the surrounding area so it can be pumped away.

Shallow Foundations

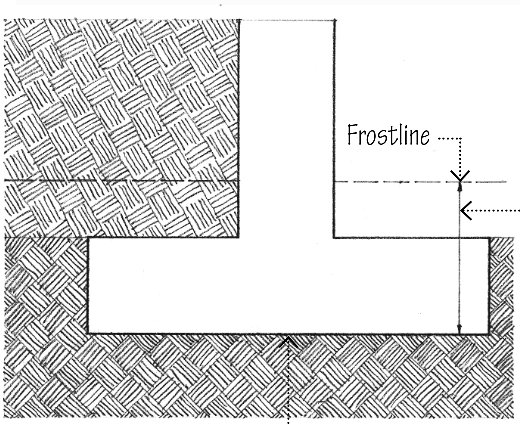
The lowest part of a shallow foundation are spread footings. They are extended laterally to distribute their load over an area of soil wide enough that the allowable bearing capacity of the soil is not exceeded.







The contact area required is equal to the quotient of the magnitude of forces transmitted and the allowable bearing capacity of the supporting soil mass.

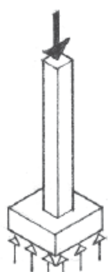


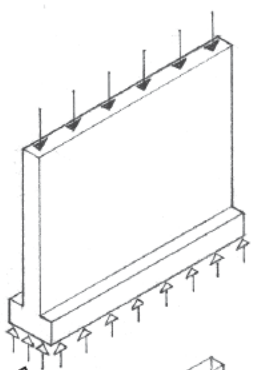
To minimize the effects of ground heaving when groundwater freezes and expands in cold weather, building codes require that footings be placed below the depth of frost penetration expected at the building site. Frostline is the average depth at which soil is frozen or frost penetrates the ground.

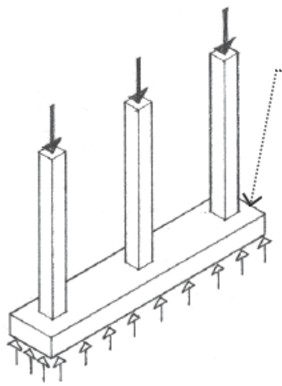
To minimize settlement, footings should always rest on stable, undisturbed soil free of organic material. When this is not possible, a specially engineered fill, compacted in 8 in. to 12 in. (205 to 305) layers at a controlled moisture content, can be used to make up the extra depth.

Spread Footings

The most common forms of spread footings are strip footings and isolated footings. Other types of spread footings are illustrated below.

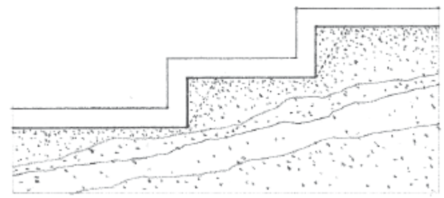






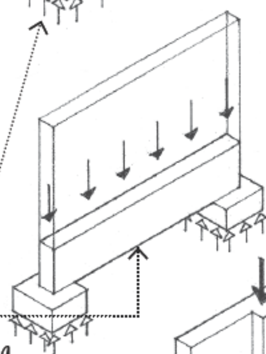
- A continuous footing is a reinforced concrete footing extended to support a row of columns.

- Isolated footings are the individual spread footings supporting freestanding columns and piers.

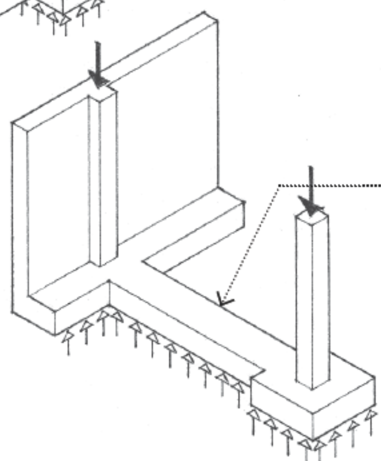


- Stepped footings are strip footings that change levels in stages to accommodate a sloping grade and maintain the required depth at all points around a building.

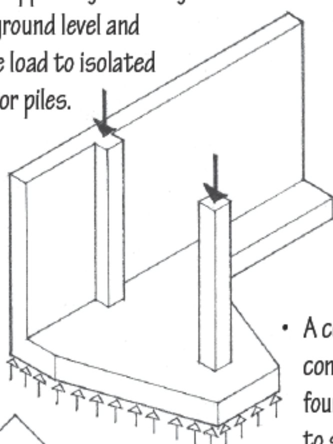
- Strip footings are the continuous spread footings of foundation walls.



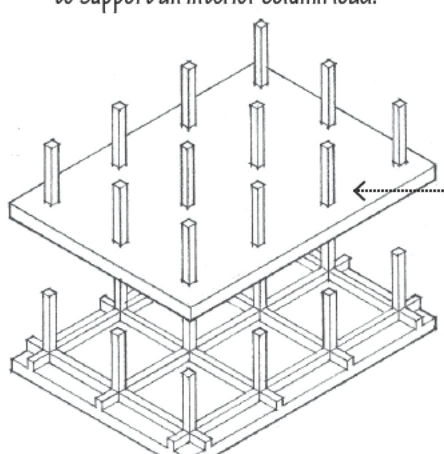
- A grade beam is a reinforced concrete beam supporting a bearing wall at or near ground level and transferring the load to isolated footings, piers, or piles.

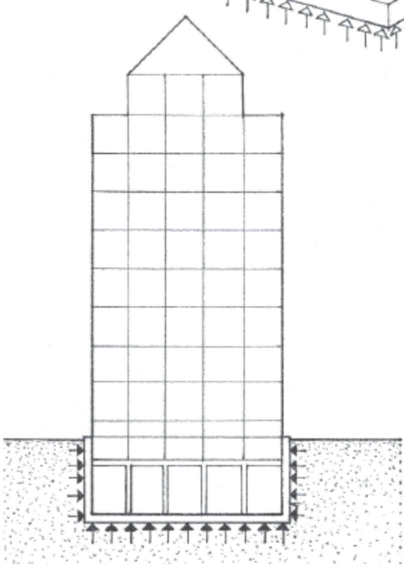


- A cantilever or strap footing consists of a column footing connected by a tie beam to another footing in order to balance an asymmetrically imposed load.
- Cantilever and combined footings are often used when a foundation abuts a property line and it is not possible to construct a symmetrically loaded footing. To prevent the rotation or differential settlement that an asymmetrical loading condition can produce, continuous and cantilever footings are proportioned to generate uniform soil pressure.



- A combined footing is a reinforced concrete footing for a perimeter foundation wall or column extended to support an interior column load.



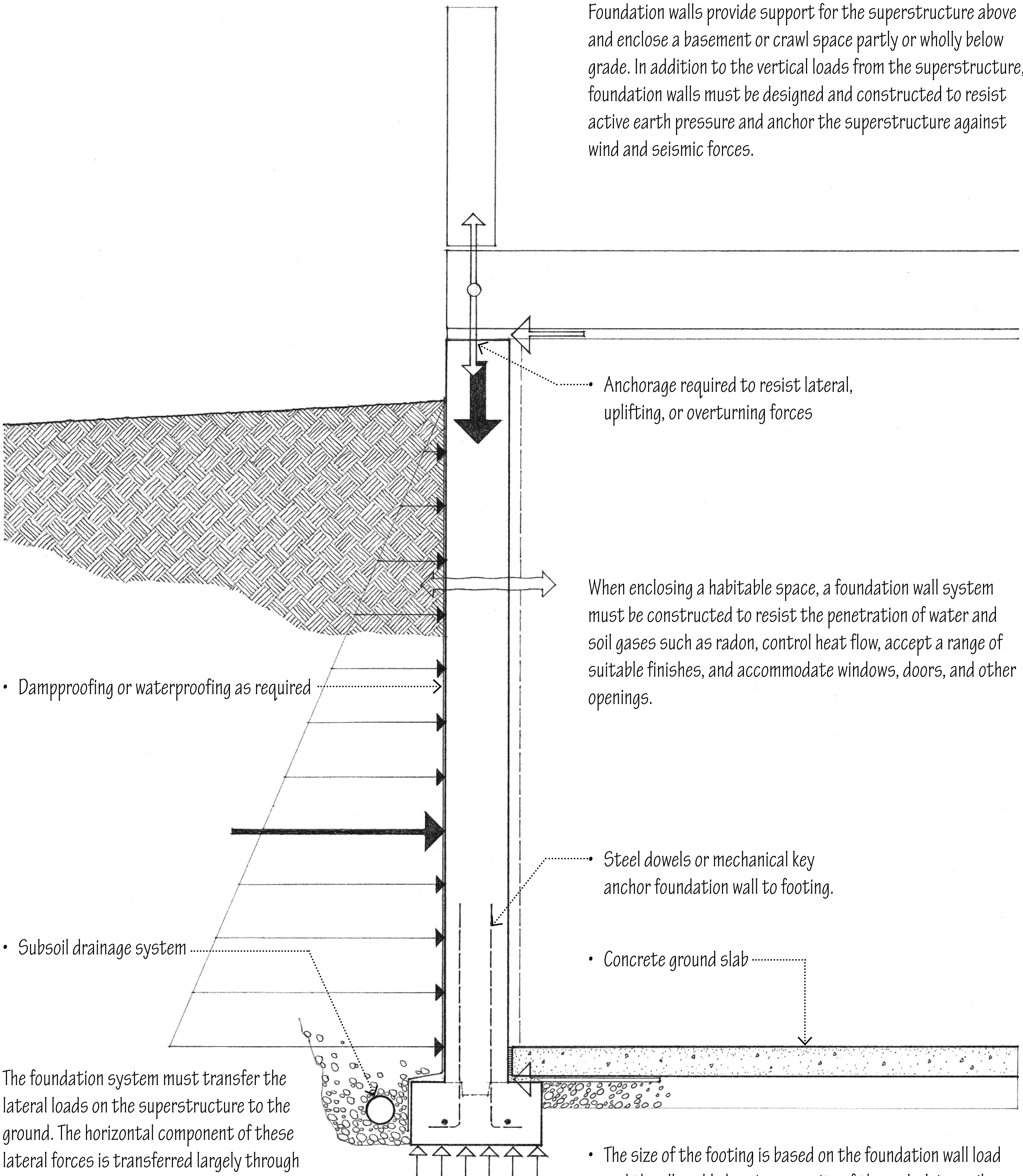


- A mat or raft foundation is a thick, heavily reinforced concrete slab that serves as a single monolithic footing for a number of columns or an entire building. Mat foundations are used when the allowable bearing capacity of a foundation soil is low relative to building loads and interior column footings become so large that it becomes more economical to merge them into a single slab. Mat foundations may be stiffened by a grid of ribs, beams, or walls.

- A floating foundation, used in yielding soil, has for its footing a mat placed deep enough that the weight of the excavated soil is equal to or greater than the weight of the construction supported.

Foundation Walls

Foundation walls provide support for the superstructure above and enclose a basement or crawl space partly or wholly below grade. In addition to the vertical loads from the superstructure, foundation walls must be designed and constructed to resist active earth pressure and anchor the superstructure against wind and seismic forces.

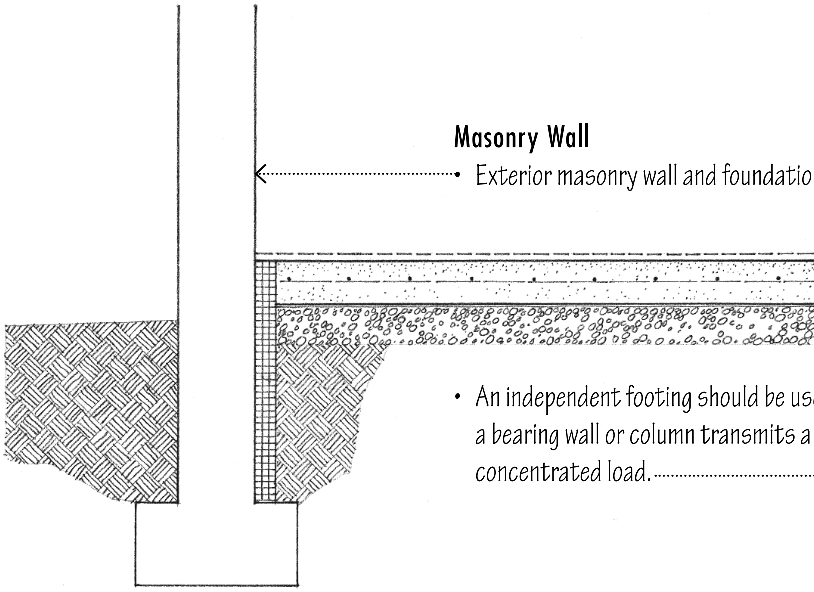


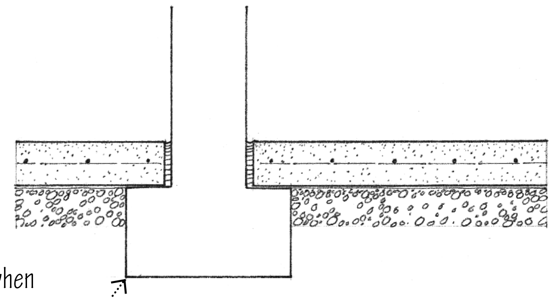
When enclosing a habitable space, a foundation wall system must be constructed to resist the penetration of water and soil gases such as radon, control heat flow, accept a range of suitable finishes, and accommodate windows, doors, and other openings.

The foundation system must transfer the lateral loads on the superstructure to the ground. The horizontal component of these lateral forces is transferred largely through a combination of soil friction on the bottom of footings and the development of passive soil pressure on the sides of footings and foundation walls.

- Isolated or integral footings are required to transmit loads from the superstructure above to the foundation soil.

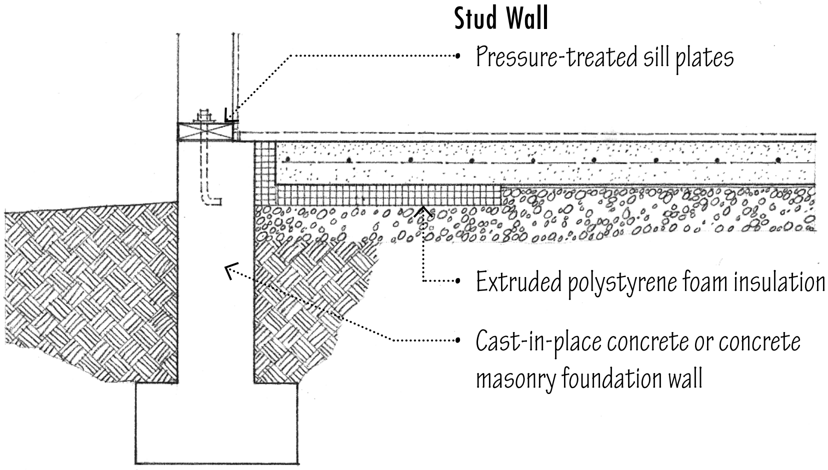
Masonry Wall
- Exterior masonry wall and foundation

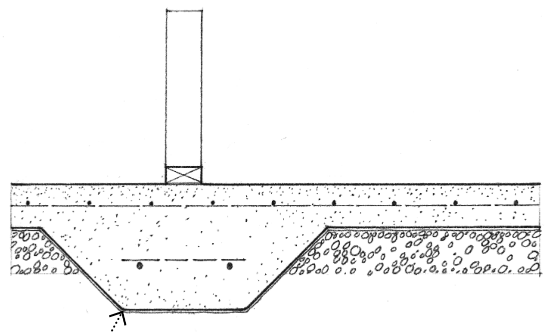




- An independent footing should be used when a bearing wall or column transmits a heavy or concentrated load.

Stud Wall
- Pressure-treated sill plates

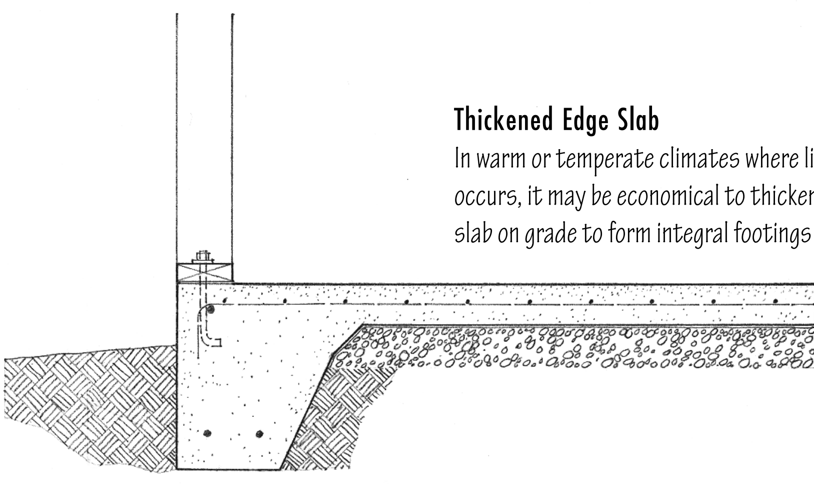




- Extruded polystyrene foam insulation
- Cast-in-place concrete or concrete masonry foundation wall
- The width and depth of the slab footing are determined by the magnitude of the load and the bearing capacity of the soil.
- A concrete ground slab may be thickened to support an interior bearing partition or post and transmit the load to the underlying soil.

Thickened Edge Slab

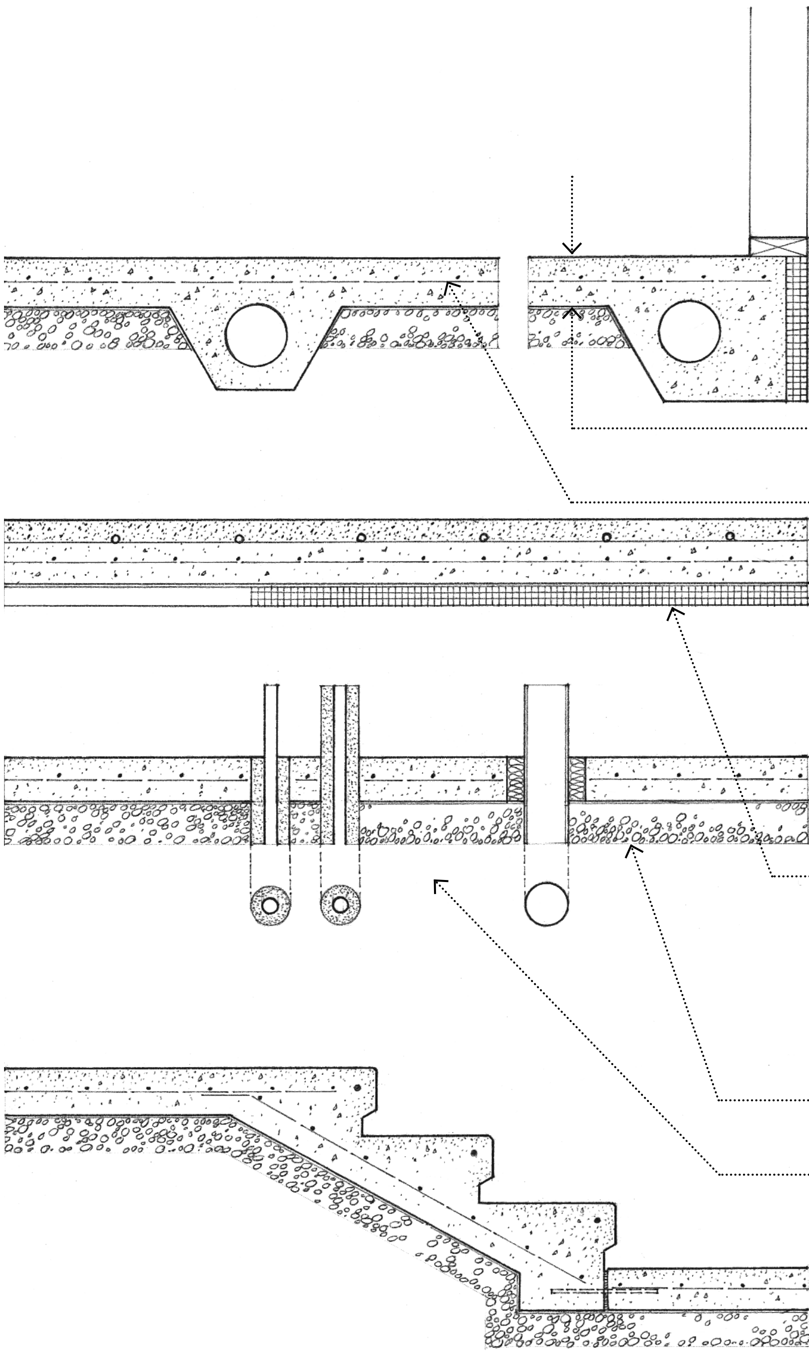
In warm or temperate climates where little or no ground frost occurs, it may be economical to thicken the edges of a concrete slab on grade to form integral footings for the exterior walls.



Concrete Slab on Grade

A concrete slab may be placed at or near grade level to serve as a combined floor and foundation system. The suitability of a concrete slab for such use depends on the geographic location, topography, and soil characteristics of the site, and the design of the superstructure.

Concrete slabs on grade require the support of a level, stable, uniformly dense or properly compacted soil base containing no organic matter. When placed over soil of low bearing capacity or over highly compressible or expansive soils, a concrete ground slab must be designed as a mat or raft foundation, which requires professional analysis and design by a qualified structural engineer.

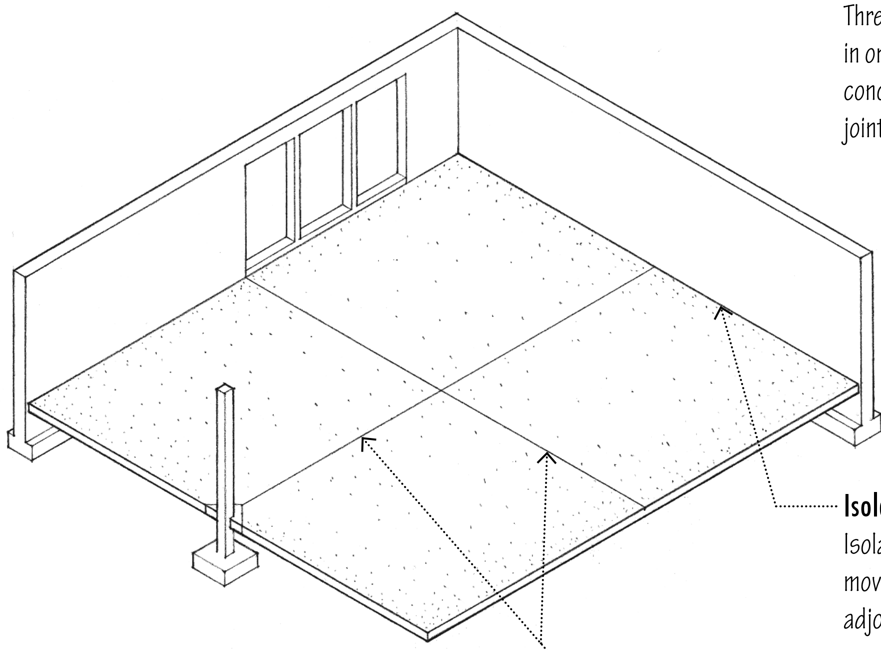


- 4 in. (100) minimum slab thickness; thickness required depends on expected use and load conditions.
- Welded wire fabric reinforcement set at or slightly above the mid-depth of the slab controls thermal stresses, shrinkage cracking, and slight differential movement in the soil bed; a grid of reinforcing bars may be required for slabs carrying heavier-than-normal floor loads.
- Concrete additives can increase surface hardness and abrasion resistance.

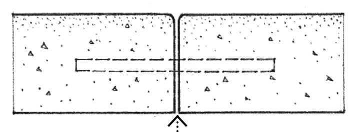
- 6-mil (0.15-mm) polyethylene moisture barrier
- Underslab insulation recommended

- The American Concrete Institute recommends a 2 in. (51) layer of sand be placed over the moisture barrier to absorb excess water from the concrete during curing.
- Base course of gravel or crushed stone to prevent the capillary rise of groundwater; 4 in. (100) minimum
- Stable, uniformly dense soil base; compaction may be required to increase soil stability, load-bearing capacity, and resistance to water penetration.

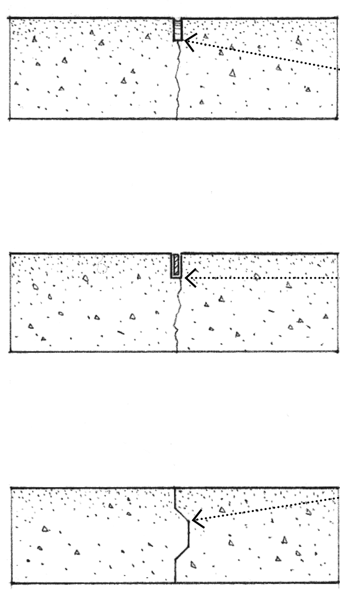
Three types of joints may be created or constructed in order to accommodate movement in the plane of a concrete slab on grade—isolation joints, construction joints, and control joints.



Isolation Joints
Isolation joints, often called expansion joints, allow movement to occur between a concrete slab and adjoining columns and walls of a building.

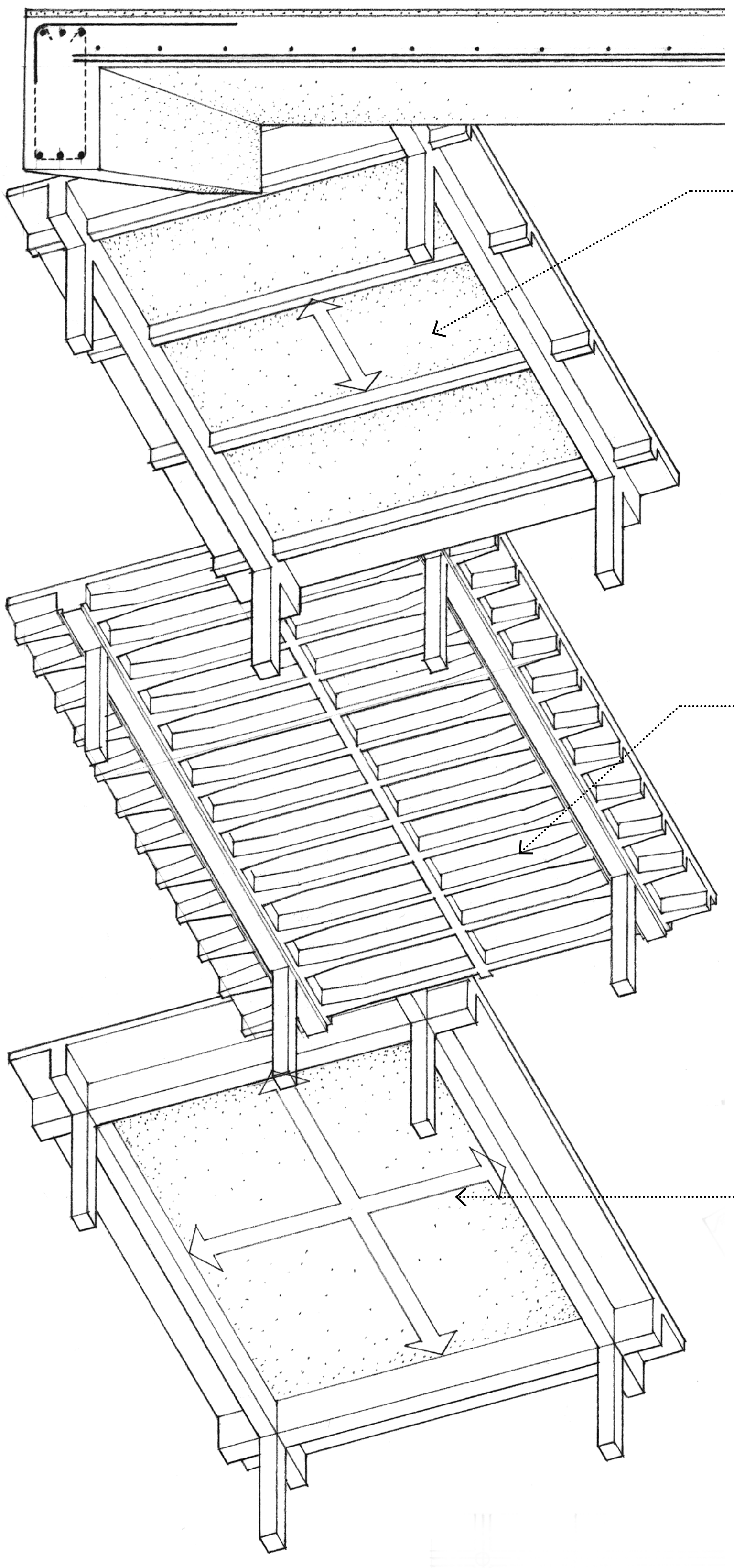


Construction Joints
Construction joints provide a place for construction to stop and then continue at a later time. These joints, which also serve as isolation or control joints, can be keyed or doweled to prevent vertical differential movement of adjoining slab sections.



Control Joints
Control joints create lines of weakness so that the cracking that may result from tensile stresses occurs along predetermined lines. Space control joints in exposed concrete 15 ft. to 20 ft. (4570 to 6095) on center, or wherever required to break an irregular slab shape into square or rectangular sections.

Floors



Concrete Floor Slabs

Concrete slabs are plate structures that are reinforced to span either one or both directions of a structural bay. Consult a structural engineer and the building code for the required size, spacing, and placement of all reinforcement.

One-Way Slab

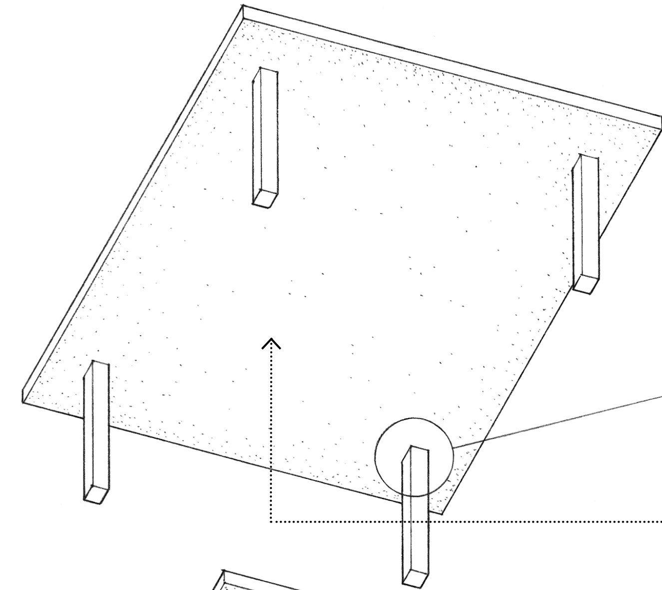
A one-way slab is uniformly thick, reinforced in one direction, and cast integrally with parallel supporting beams.

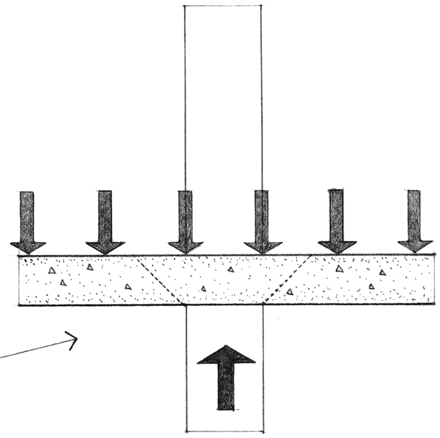
One-Way Joist Slab

A joist or ribbed slab is cast integrally with a series of closely spaced joists, which in turn are supported by a parallel set of beams. Designed as a series of T-beams, joist slabs are more suitable for longer spans and heavier loads than one-way slabs.

Two-Way Slab and Beam

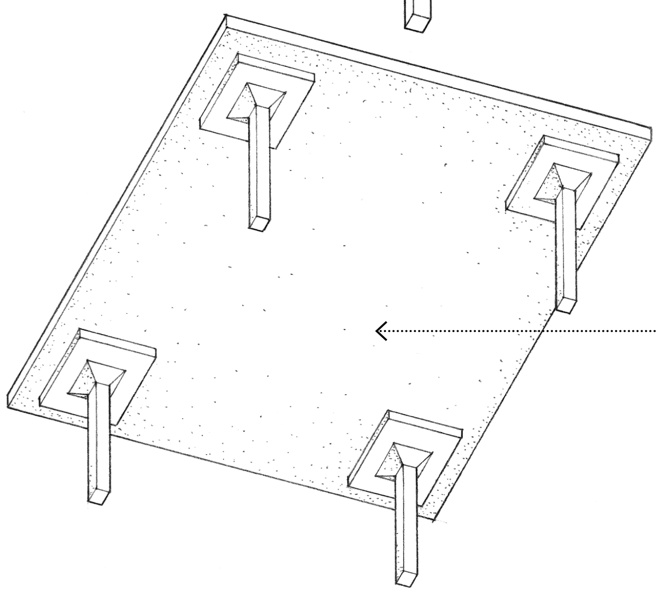
A two-way slab of uniform thickness may be reinforced in two directions and cast integrally with supporting beams and columns on all four sides of square or nearly square bays. Two-way slab and beam construction is effective for medium spans and heavy loads, or when a high resistance to lateral forces is required. For economy, however, two-way slabs are usually constructed as flat slabs and plates without beams.





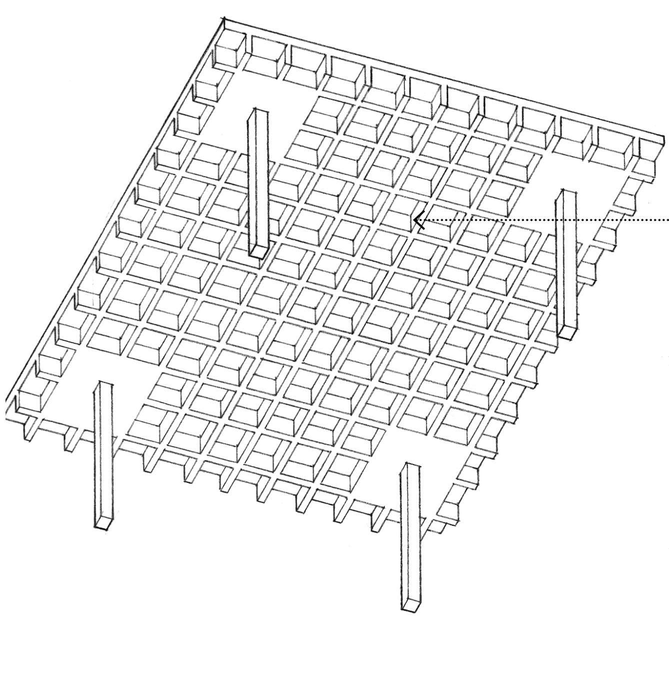
Two-Way Flat Plate

A flat plate is a concrete slab of uniform thickness reinforced in two or more directions and supported directly by columns without beams or girders. Simplicity of forming, lower floor-to-floor heights, and some flexibility in column placement make flat plates practical for apartment and hotel construction.



Two-Way Flat Slab

A flat slab is a flat plate thickened at its column supports to increase its shear strength and moment-resisting capacity.



Two-Way Waffle Slab

A waffle slab is a two-way concrete slab reinforced by ribs in two directions. Waffle slabs are able to carry heavier loads and span longer distances than flat slabs.

Prestressed Concrete

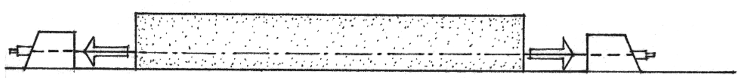
Prestressed concrete is reinforced by pretensioning or posttensioning high-strength steel tendons within their elastic limit to actively resist a service load. The tensile stresses in the tendons are transferred to the concrete, placing the entire cross section of the flexural member in compression. The resulting compressive stresses counteract the tensile bending stresses from the applied load, enabling the prestressed member to deflect less, carry a greater load, or span a greater distance than a conventionally reinforced member of the same size, proportion, and weight.

There are two types of prestressing techniques. Pretensioning is accomplished in a precasting plant, whereas posttensioning is usually performed at the building site, especially when the structural units are too large to transport from factory to site.

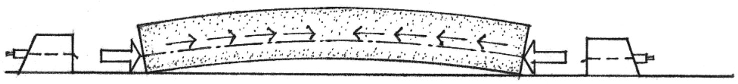
Pretensioning

Pretensioning prestresses a concrete member by stretching the reinforcing tendons before the concrete is cast.

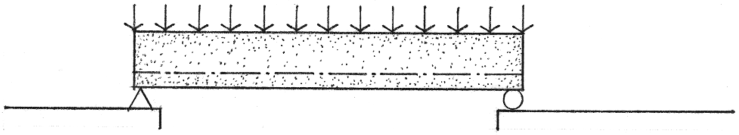
- Steel tendons are first stretched across the casting bed between two abutments until a predetermined tensile force is developed.



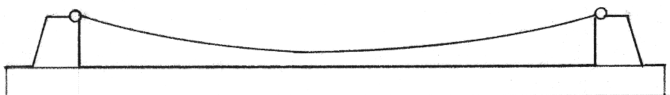
- Concrete is then cast in formwork around the stretched tendons and fully cured. The tendons are placed eccentrically in order to reduce the maximum compressive stress to that produced by bending alone.



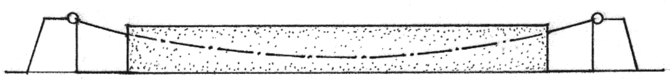
- When the tendons are cut or released, the tensile stresses in the tendons are transferred to the concrete through bond stresses. The eccentric action of the prestressing produces a slight upward curvature or camber in the member.



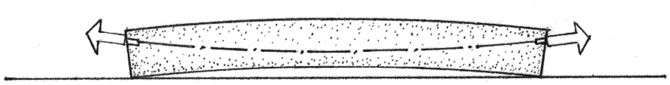
- The deflection of the member under loading tends to equalize its upward curvature.



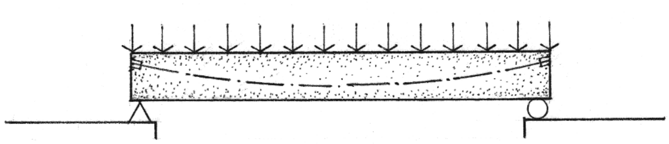
• Unstressed steel tendons, draped inside the beam or slab form, are coated or sheathed to prevent bonding while the concrete is cast.



• After the concrete has cured, the tendons are clamped on one end and jacked against the concrete on the other end until the required force is developed.



• The tendons are then securely anchored on the jacking end and the jack removed. After the posttensioning process, the steel tendons may be left unbonded, or they may be bonded to the surrounding concrete by injecting grout into the annular spaces around the sheathed strands.



• The deflection of the member under loading tends to equalize its upward curvature.

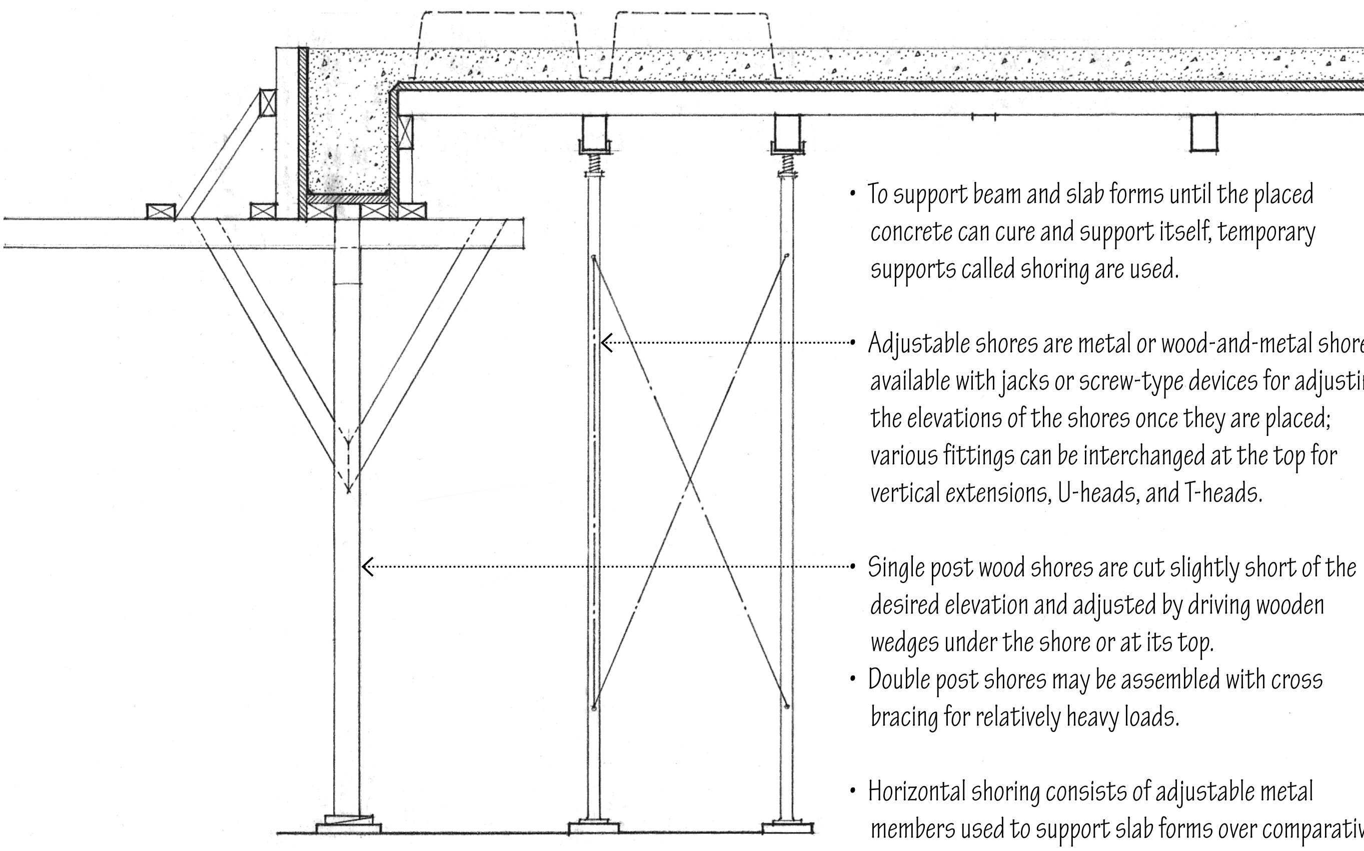
Posttensioning

Posttensioning is the prestressing of a concrete member by tensioning the reinforcing tendons after the concrete has set.

Posttensioned members tend to shorten over time because of elastic compression, shrinkage, and creep. Adjoining elements that would be affected by this movement should be constructed after the posttensioning process is completed and be isolated from the posttensioned members with expansion joints.

Concrete Shoring and Formwork

Fresh concrete must be shaped and supported by formwork until it cures and can support itself. This formwork is often designed as a separate structural system by an engineer because of the considerable weight and fluid pressure a concrete mass can exert on it.



- To support beam and slab forms until the placed concrete can cure and support itself, temporary supports called shoring are used.

- Adjustable shores are metal or wood-and-metal shores available with jacks or screw-type devices for adjusting the elevations of the shores once they are placed; various fittings can be interchanged at the top for vertical extensions, U-heads, and T-heads.

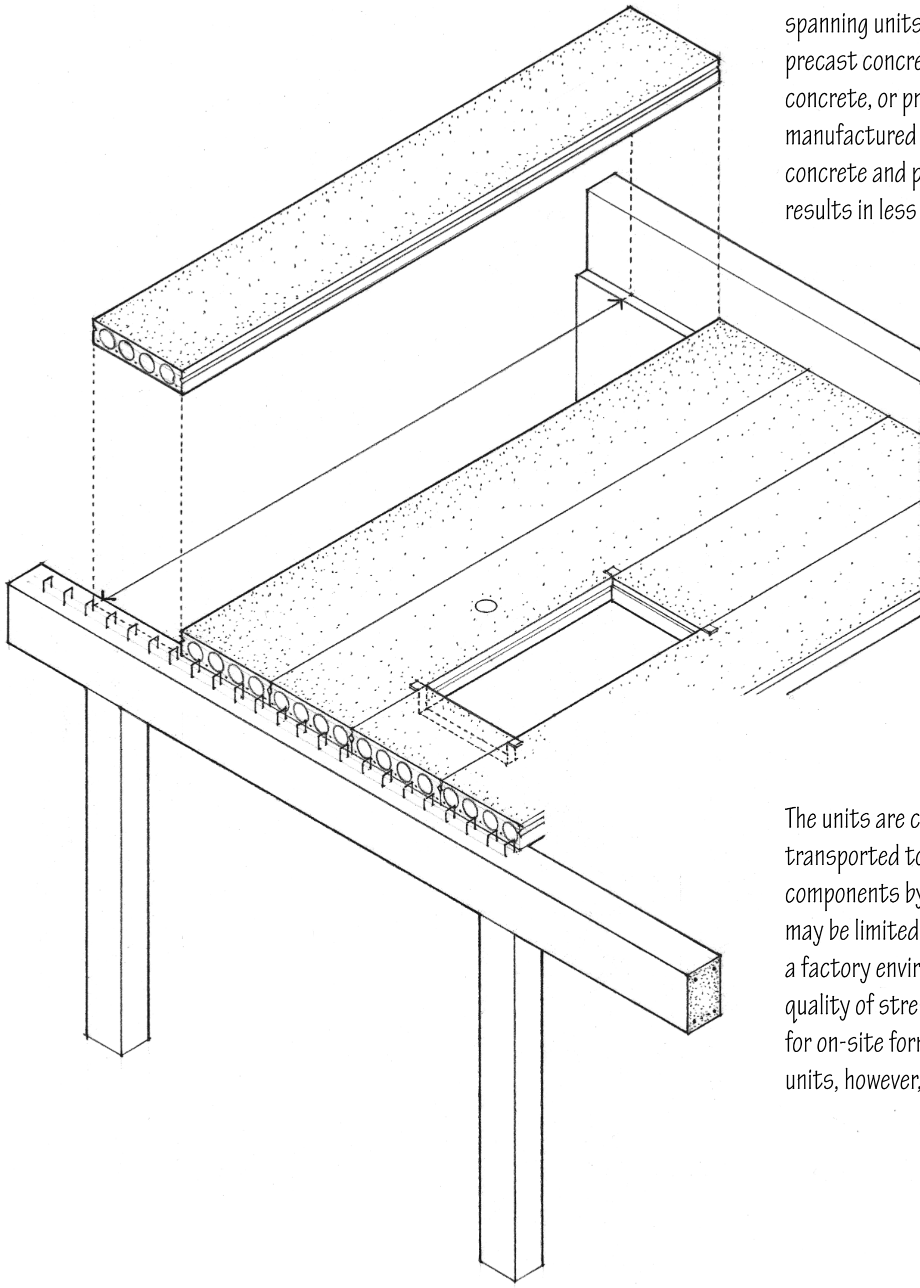
- Single post wood shores are cut slightly short of the desired elevation and adjusted by driving wooden wedges under the shore or at its top.
- Double post shores may be assembled with cross bracing for relatively heavy loads.

- Horizontal shoring consists of adjustable metal members used to support slab forms over comparatively long spans without intervening vertical shores. Horizontal shoring requires fewer vertical shores, each carrying a comparatively greater load, and leaves open spaces clear for work, but each vertical support carries a greater concentration of load.

- After a concrete slab or beam has cured sufficiently to carry its own weight, the original formwork is removed and the slab or beam is reshored until the concrete reaches it full strength.

Precast Concrete Floor Systems

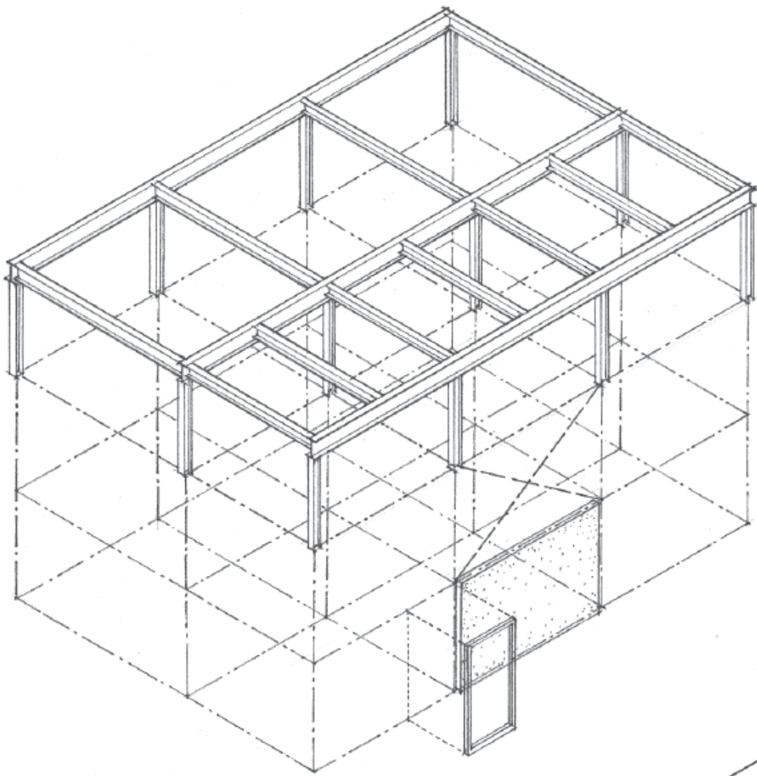
Precast concrete slabs, beams, and structural tees are one-way spanning units that may be supported by sitecast concrete, precast concrete, or masonry bearing walls, or by steel, sitecast concrete, or precast concrete frames. The precast units are manufactured with normal-density or structural lightweight concrete and prestressed for greater structural efficiency, which results in less depth, reduced weight, and longer spans.

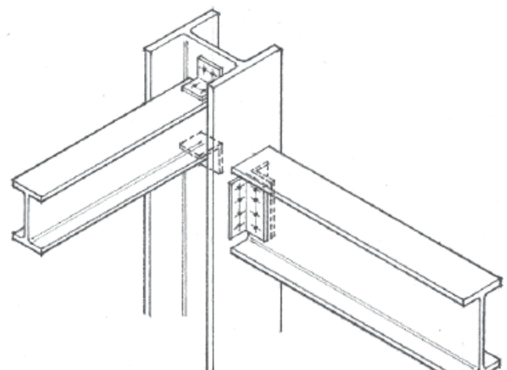


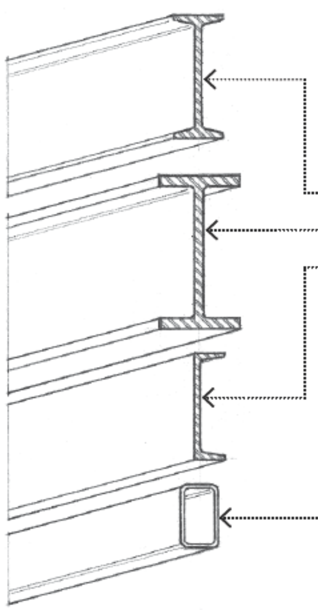
The units are cast and steam-cured in a plant off-site, transported to the construction site, and set in place as rigid components by cranes. The size and proportion of the units may be limited by the means of transportation. Fabrication in a factory environment enables the units to have a consistent quality of strength, durability, and finish, and eliminates the need for on-site formwork. The modular nature of the standard-sized units, however, may not be suitable for irregular building shapes.

Structural Steel Framing

Structural steel girders, beams, and columns are used to construct a skeleton frame for structures ranging in size from one-story buildings to skyscrapers. Because structural steel is difficult to work on-site, it is normally cut, shaped, and drilled in a fabrication shop according to design specifications; this can result in relatively fast, precise construction of a structural frame. Structural steel may be left exposed in unprotected noncombustible construction, but because steel can lose strength rapidly in a fire, fire-rated assemblies or coatings are required to qualify as fire-resistive construction. In exposed conditions, corrosion resistance is also required.







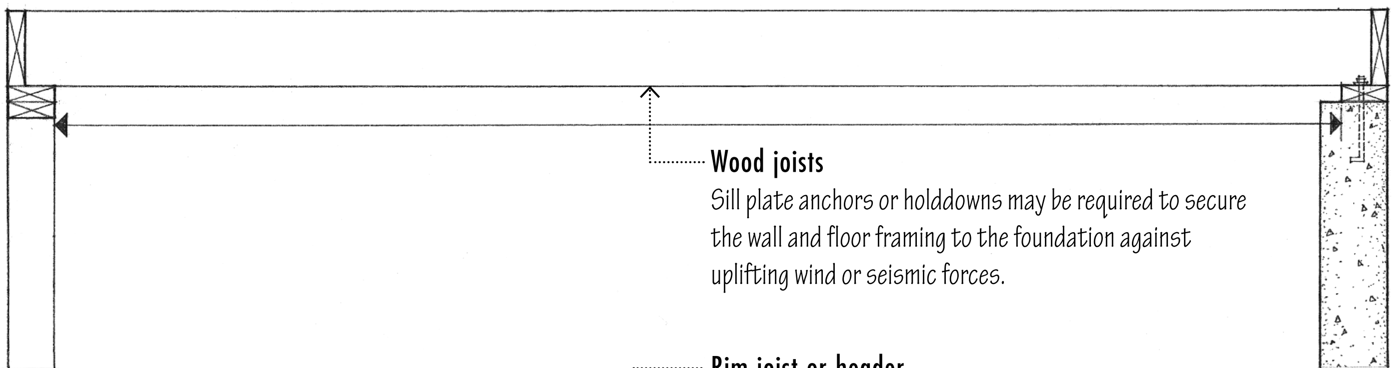
Steel Beams

- S shape
- W shape
- C shape
- Structural tubing

More structurally efficient wide-flange (W) shapes have largely superseded the classic I-beam (S) shapes. Beams may also be in the form of channel (C) sections, structural tubing, or composite sections.

Wood Joist Framing

Wood joists may be supported by wood or steel beams. In either case, the elevation of the beam should be coordinated with the perimeter sill condition and how the beam supports the floor joists. Wood is most susceptible to shrinkage perpendicular to its grain. For this reason, the total depth of wood construction for both the sill condition and the joist–beam connection should be equalized to avoid subsidence of the floor plane.

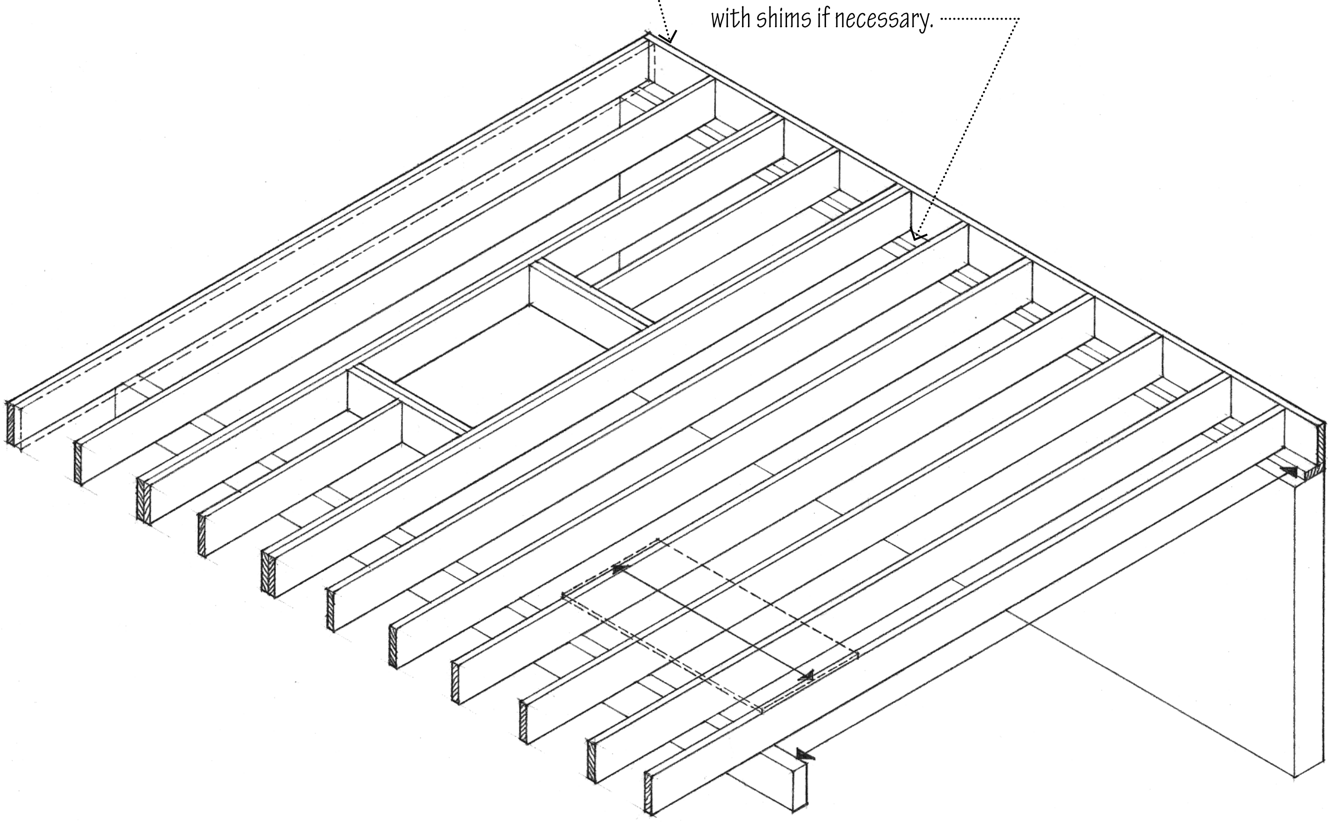


Wood joists

Sill plate anchors or holddowns may be required to secure the wall and floor framing to the foundation against uplifting wind or seismic forces.

Rim joist or header

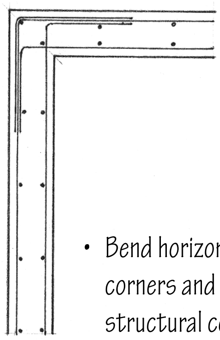
Sill plate transfers floor and wall loads to foundation; lay over fibrous sill sealer to reduce air infiltration, and level with shims if necessary.

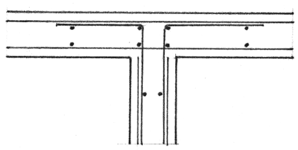


Walls

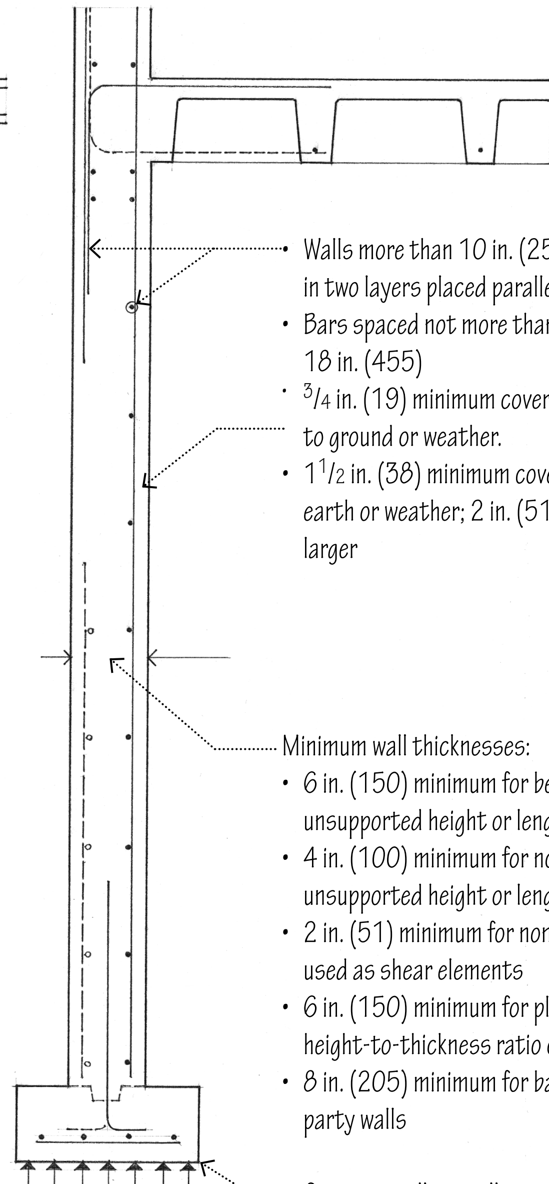
Concrete Walls

Anchor reinforced concrete walls to floor slabs, columns, and intersecting walls with bars every 12 in. (305) for each layer of wall reinforcement.





- Bend horizontal reinforcement at corners and wall intersections for structural continuity.



- Walls more than 10 in. (255) thick require reinforcement in two layers placed parallel with the faces of the wall.
- Bars spaced not more than 3 x wall thickness or every 18 in. (455)
- $^3/_4$ in. (19) minimum cover when concrete is not exposed to ground or weather.
- $1^1/_2$ in. (38) minimum cover when concrete is exposed to earth or weather; 2 in. (51) minimum for No. 6 bars and larger

Minimum wall thicknesses:

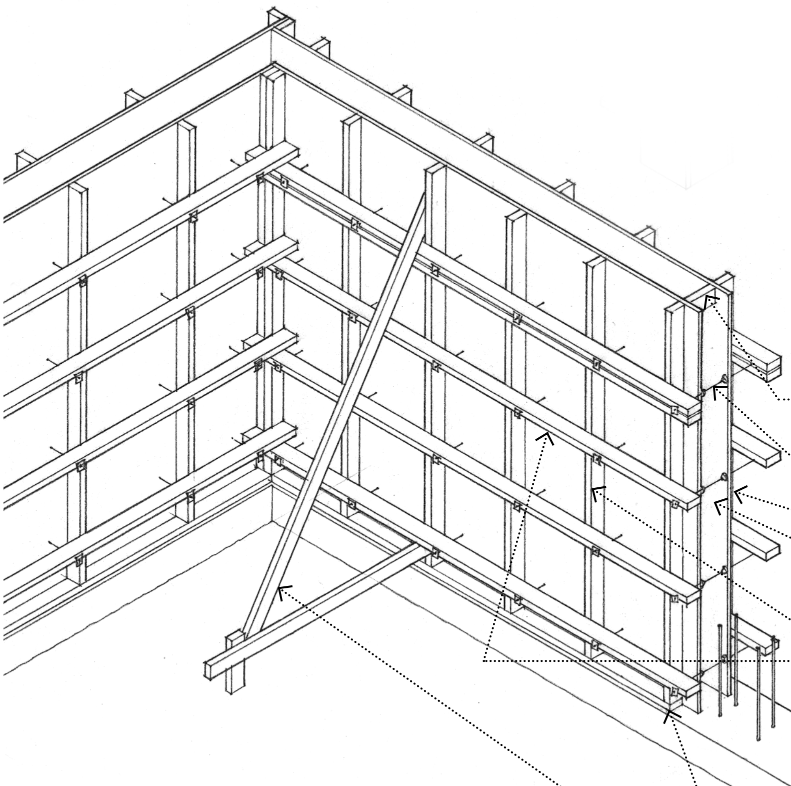
- 6 in. (150) minimum for bearing walls or $^1/_{25}$ of the unsupported height or length between stiffening elements
- 4 in. (100) minimum for nonbearing walls or $^1/_{36}$ of unsupported height or length
- 2 in. (51) minimum for nonbearing interior partitions not used as shear elements
- 6 in. (150) minimum for plain (unreinforced) walls with a height-to-thickness ratio of less than 22
- 8 in. (205) minimum for basement, foundation, fire, or party walls

- Concrete walls usually rest on a continuous strip footing.
- Wall is tied to its footing with dowels bent in alternate directions.
- 6 in. (150) minimum above reinforcement
- 3 in. (75) minimum cover when concrete is cast against and permanently exposed to the earth

Concrete Wall Formwork

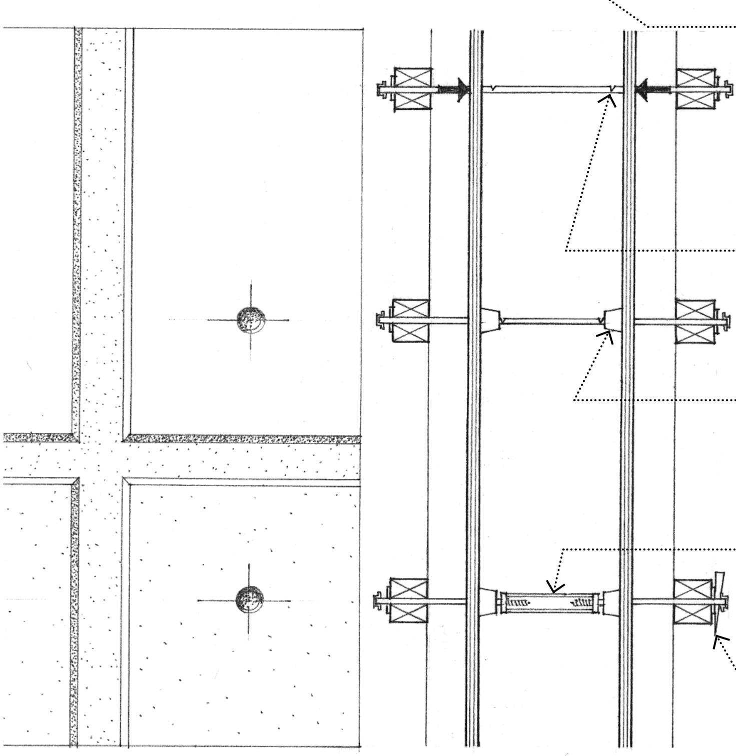
Concrete formwork for columns and walls may be custom-built for a specific job, but prefabricated, reusable panels are used whenever possible. The framework and bracing must be able to maintain the position and shape of the forms until the concrete sets.

The contact surfaces of forms are coated with a parting compound—oil, wax, or plastic—to aid in their removal. From a design standpoint, the shape of a concrete section must allow for the easy removal of the formwork. Tapered sections are used where the formwork might otherwise be trapped by the surrounding concrete. Sharp external corners are usually beveled or rounded to avoid chipping.



Wall Forms

- Spreaders, usually of wood, space and keep the wall or forms apart.
- Form ties
- Plywood sheathing
- Inner surface of panels leaves an impression on the concrete
- Wood studs
- Horizontal walers reinforce the vertical members of formwork.
- If necessary, strongbacks provide vertical support for aligning and reinforcing walers.
- Sill plate
- Bracing



- Form ties are required to keep wall forms from spreading under the fluid pressure of newly placed concrete. While various proprietary forms are available, there are two basic types: snap ties and she bolts.
- Snap ties have notches or crimps that allow their ends to be snapped off below the concrete surface after stripping of the forms. Either cones or washers are used to maintain the correct wall thickness.
- Small, truncated cones of wood, steel, or plastic, attached to form ties to space and spread wall forms, leave a neatly finished depression in the concrete surface to be filled or left exposed.
- She bolts consist of waler rods that are inserted through the form and threaded onto the ends of an inner rod. After stripping, the waler rods are removed for reuse while the inner rod remains in the concrete.
- A variety of wedges and slotted devices tighten the formwork and transfer the force in a form tie to the walers.

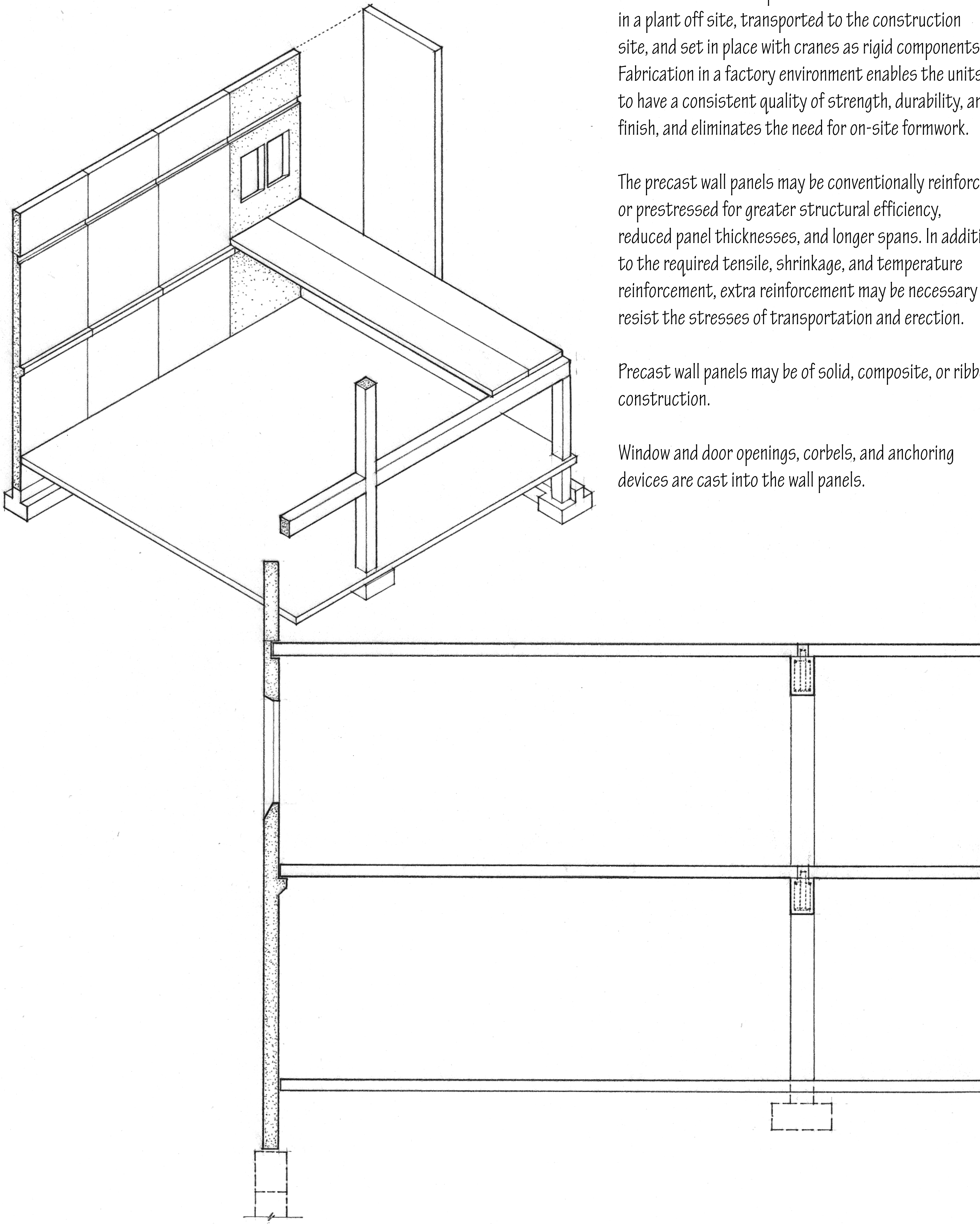
Precast Concrete Walls

Precast concrete wall panels are cast and steam-cured in a plant off site, transported to the construction site, and set in place with cranes as rigid components. Fabrication in a factory environment enables the units to have a consistent quality of strength, durability, and finish, and eliminates the need for on-site formwork.

The precast wall panels may be conventionally reinforced or prestressed for greater structural efficiency, reduced panel thicknesses, and longer spans. In addition to the required tensile, shrinkage, and temperature reinforcement, extra reinforcement may be necessary to resist the stresses of transportation and erection.

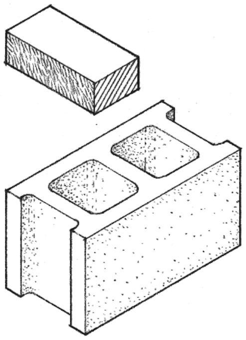
Precast wall panels may be of solid, composite, or ribbed construction.

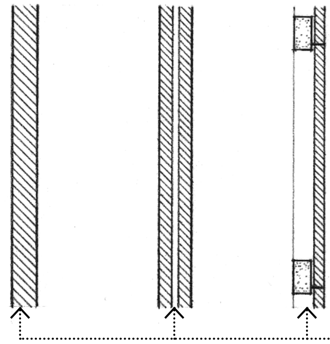
Window and door openings, corbels, and anchoring devices are cast into the wall panels.



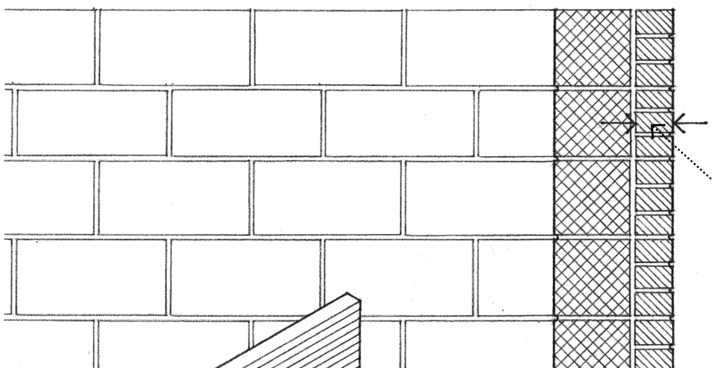
Masonry Walls

Masonry walls consist of modular building blocks bonded together with mortar to form walls that are durable, fire resistant, and structurally efficient in compression. The most common types of masonry units are bricks, which are heat-hardened clay units, and concrete blocks, which are chemically hardened units. Other types of masonry units include structural clay tile, structural glass block, and natural or cast stone.

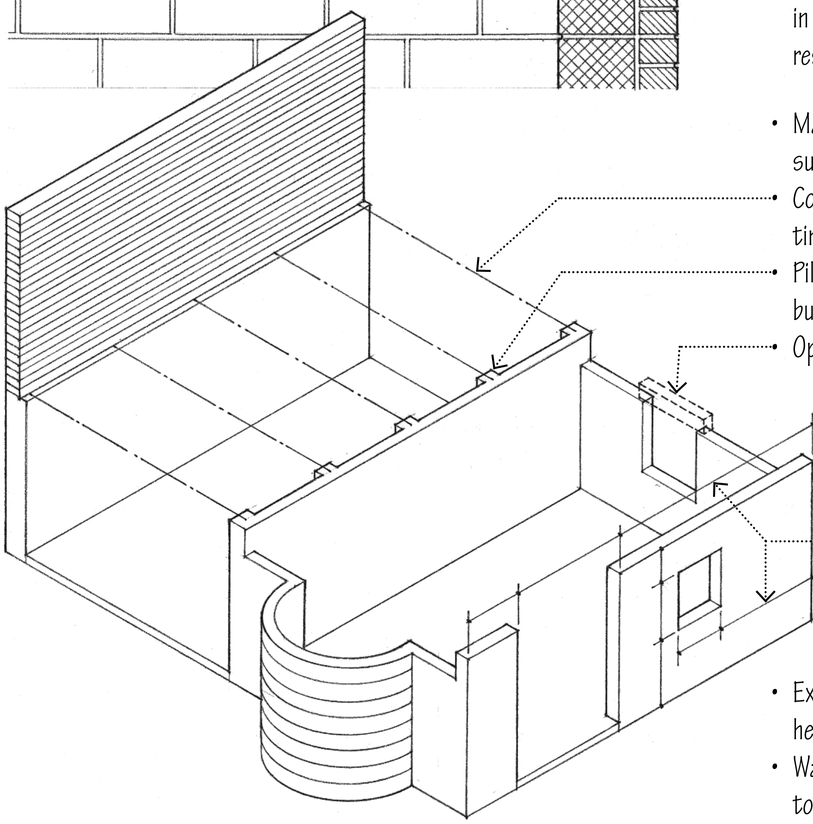




- Masonry walls may be constructed as solid walls, cavity walls, or veneered walls.



- Masonry walls may be unreinforced or reinforced.
- Unreinforced masonry walls, also called plain masonry, incorporate horizontal joint reinforcement and metal wall ties to bond the wythes of a solid or cavity wall.
- A wythe refers to a continuous vertical section of a wall that is one masonry unit in thickness.
- Reinforced masonry walls use steel reinforcing bars embedded in grout-filled joints and cavities to aid the masonry in resisting stresses.



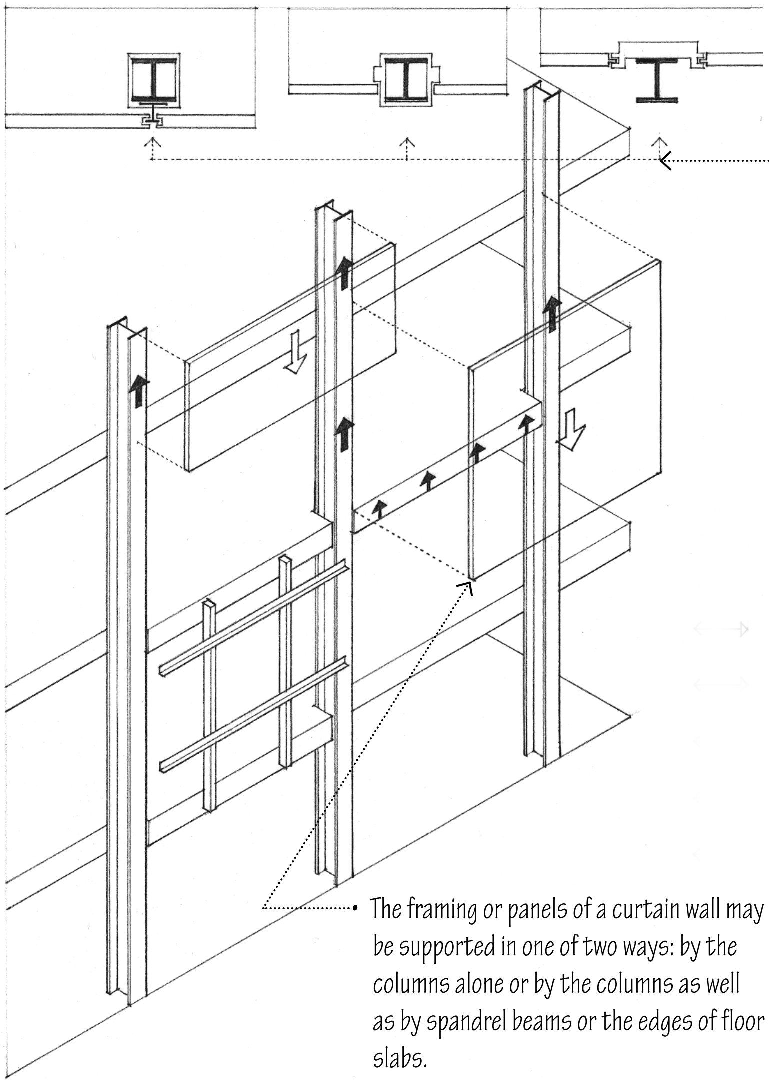
- Masonry bearing walls are typically arranged in parallel sets to support steel, wood, or concrete spanning systems.
- Common spanning elements include open-web steel joists, timber or steel beams, and sitecast or precast concrete slabs.
- Pilasters stiffen masonry walls against lateral forces and buckling, and provide support for large concentrated loads.
- Openings may be arched or spanned with lintels.

- Modular dimensions

- Exterior masonry walls must be weather resistant and control heat flow.
- Water penetration must be controlled through the use of tooled joints, cavity spaces, flashing, and caulking.
- Cavity walls are preferred for their increased resistance to water penetration and improved thermal performance.
- Differential movements in masonry walls because of changes in temperature or moisture content, or to stress concentrations, require the use of expansion and control joints.

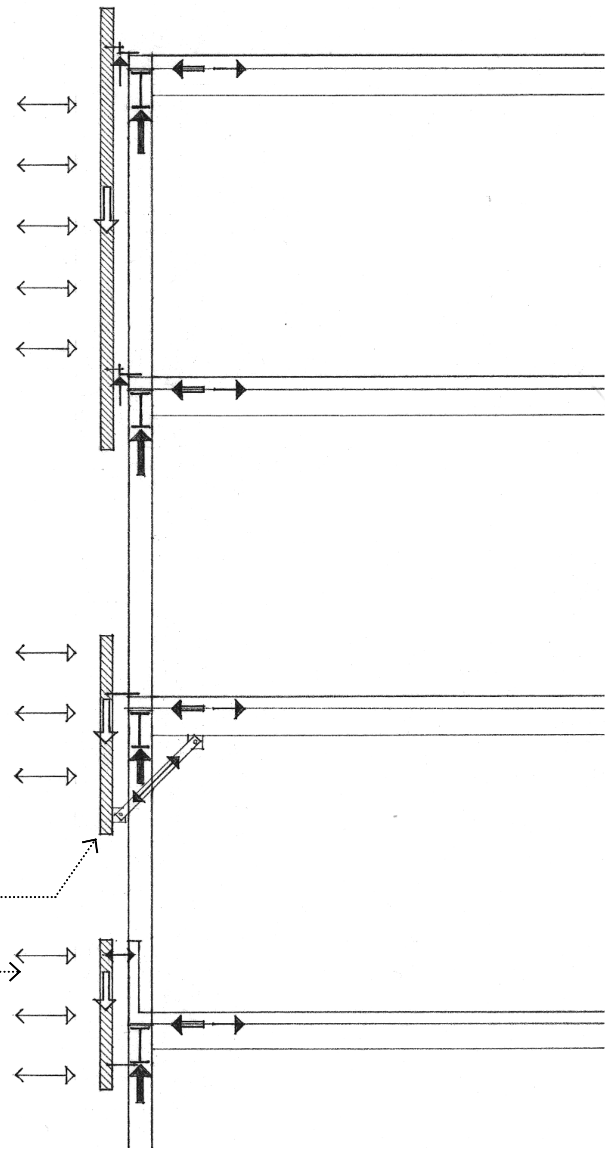
Structural Steel Framing

Conventional steel-framed structures are constructed of hot-rolled beams and columns, open-web joists, and metal decking. Since structural steel is difficult to work on site, it is normally cut, shaped, and drilled in a fabrication shop according to design specifications; this can result in relatively fast, precise construction.

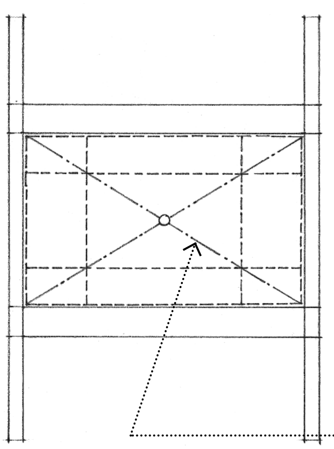


Because the columns in a steel frame structure transfer the gravity and lateral loads down to the foundation system, the exterior walls are essentially non-load-bearing curtain walls. There are three basic relationships that may be established between a structural steel frame and the curtain wall or cladding it supports.

- Column in front of the wall plane
- Column within the wall plane
- Column behind the wall plane



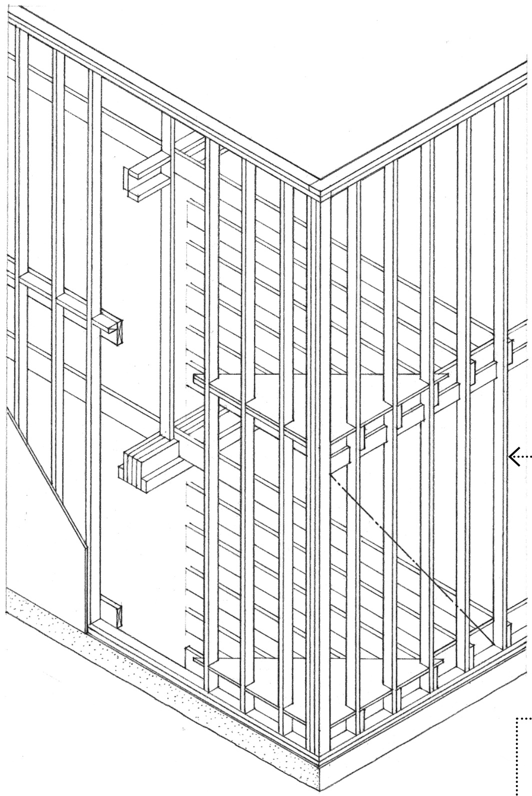
- The framing or panels of a curtain wall may be supported in one of two ways: by the columns alone or by the columns as well as by spandrel beams or the edges of floor slabs.
- Wall units incapable of spanning columns or from floor to floor require secondary framing of mullions and shelf angles.
- The curtain wall framing or panels and the supporting structural frame may respond differently to variations in temperature and to gravity or wind loads. Connection details should allow for the differential movement between the wall and structural frame, as well as between the wall units themselves.
- The wall may be subject to both wind pressure and suction.
- If diagonals are used to brace the structural frame, they will affect the design of the wall units.



Stud Wall Framing

Factors to consider in the selection of an exterior wall finish for stud wall frames include:

- Stud spacing required
- Sheathing or backing requirements
- Color, texture, pattern, and scale desired
- Standard widths and heights of panel siding
- Detailing of corners and vertical and horizontal joints
- Integration of door and window openings into wall pattern
- Durability, maintenance requirements, and weathering characteristics
- Heat conductivity, reflectance, and porosity of the material
- Expansion joints, if required

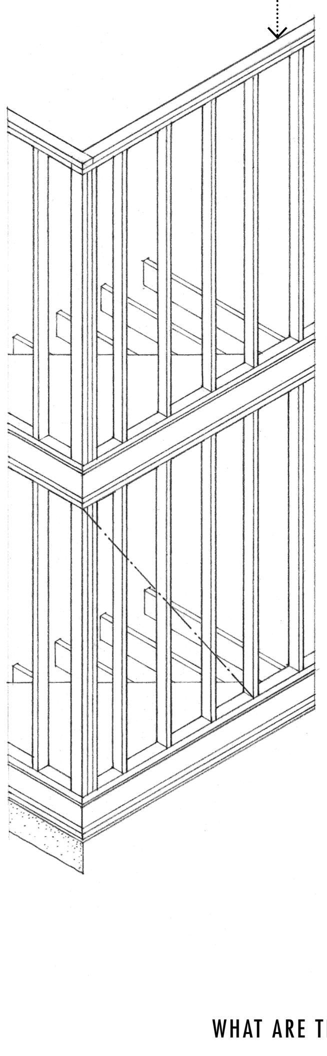


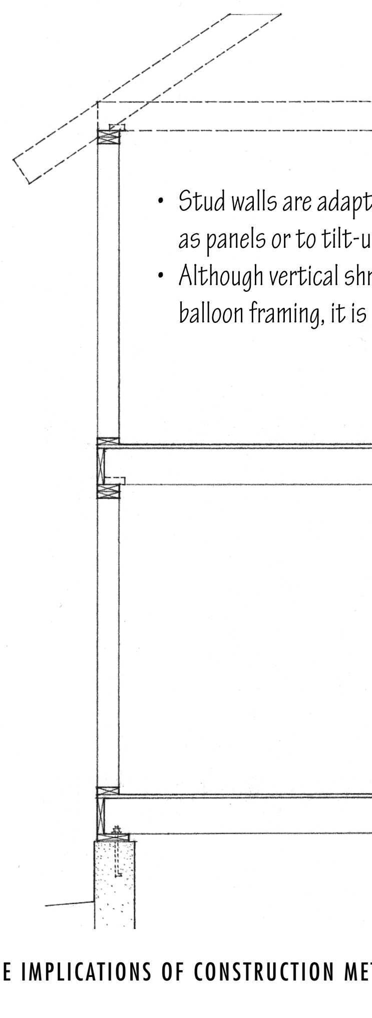
Balloon Framing

Balloon framing uses studs that rise the full height of the frame from the sill plate to the roof plate, with joists nailed to the studs and supported by sills or by ribbons let into the studs. Balloon framing is rarely used today but the minimal vertical shrinkage it affords may be desirable for brick veneer and stucco finishes.

Platform Framing

Platform framing is a light wood frame having studs only one story high, regardless of the stories built, each story resting on the top plates of the story below or on the sill plates of the foundation wall. Platform framing is also referred to as western framing.



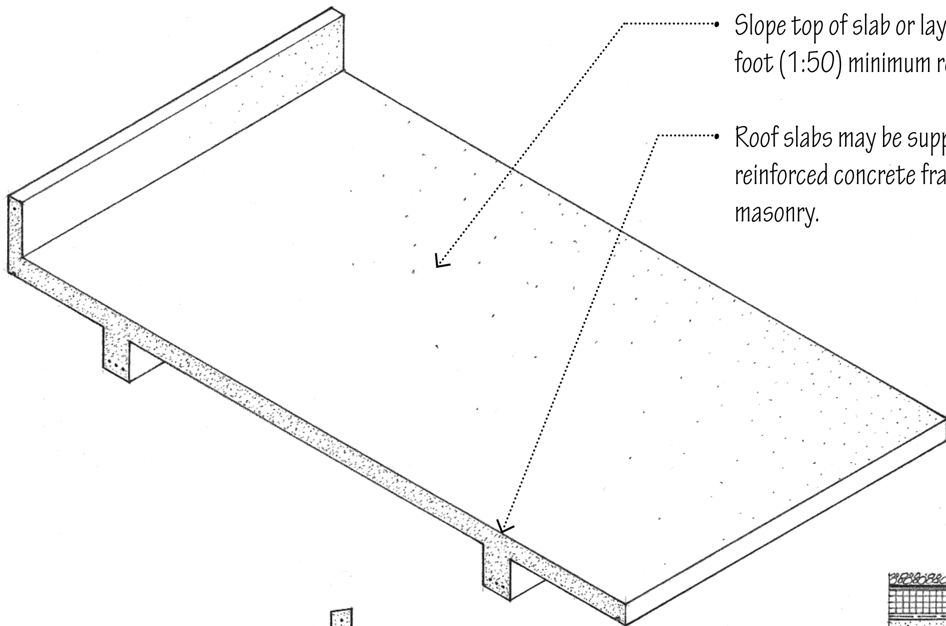


- Stud walls are adaptable to off-site fabrication as panels or to tilt-up construction.
- Although vertical shrinkage is greater than in balloon framing, it is equalized between floors.

Roofs

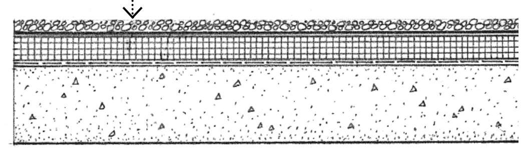
Concrete Roof Slabs

Reinforced concrete roof slabs are formed and sitecast in the same manner as concrete floor systems. Roof slabs are normally covered with a type of membrane roofing shown in the cross section that follows.

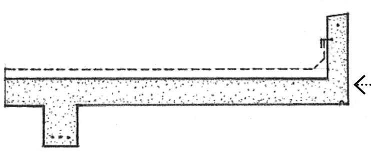


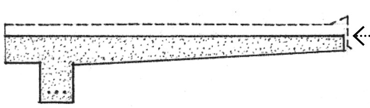
For flat roof assemblies:

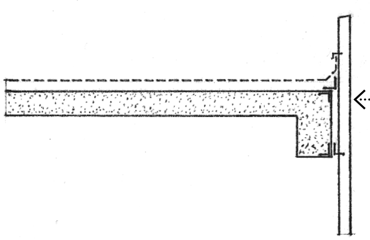
- Slope top of slab or layer of roof insulation for roof drainage; 1/4 in. per foot (1:50) minimum recommended.
- Roof slabs may be supported by reinforced concrete columns, reinforced concrete frames, or bearing walls of reinforced concrete or masonry.



- Built-up roofing or roofing membrane over rigid foam insulation and vapor retarder







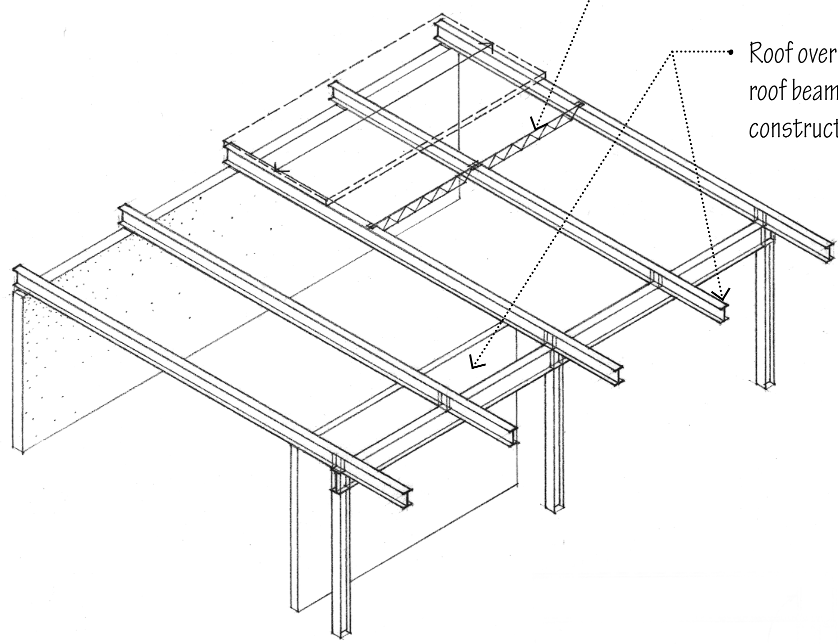
The edge of a concrete roof slab may be treated in three different ways:

- An upturned edge beam can form a parapet wall.
- A metal reglet may be cast into the parapet to receive cap flashing.
- The slab can be cantilevered beyond its perimeter supports to form an overhang.
- An edge or spandrel beam can support a nonbearing curtain wall.
- Metal anchors may be cast into the spandrel beams to secure the curtain wall panels.

Structural Steel Roof Framing

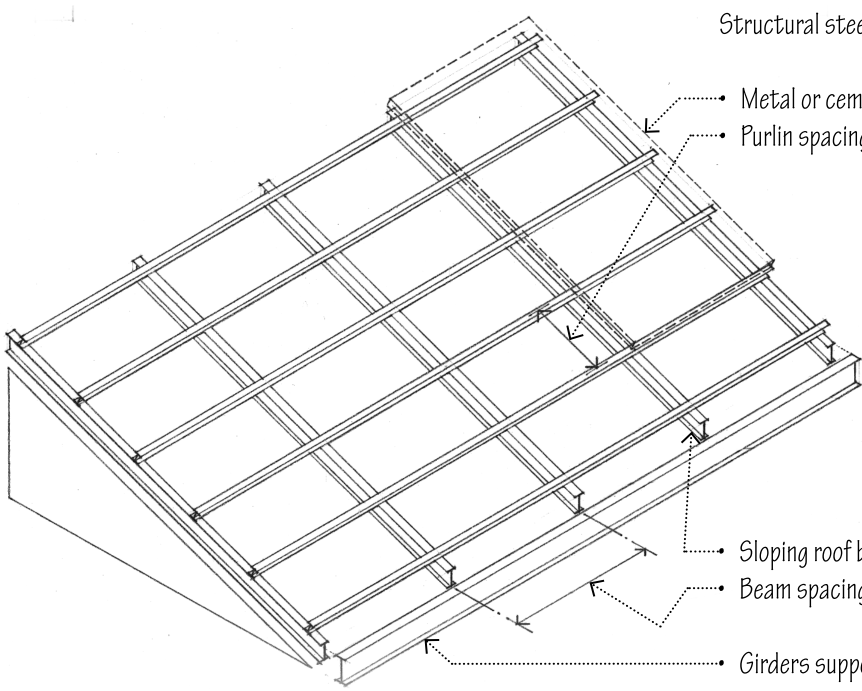
A flat roof structure may be framed with structural steel members similar to the way steel floors are framed.

- The primary and secondary roof beams may support open-web steel joists, metal roof decking, a sitecast concrete slab, or precast concrete units.
- Roof overhangs may be achieved by extending the secondary roof beams over their supports or by recessing the exterior wall construction.



Structural steel can also be used to frame sloping roofs.

- Metal or cementitious roof decking
- Purlin spacing = decking span

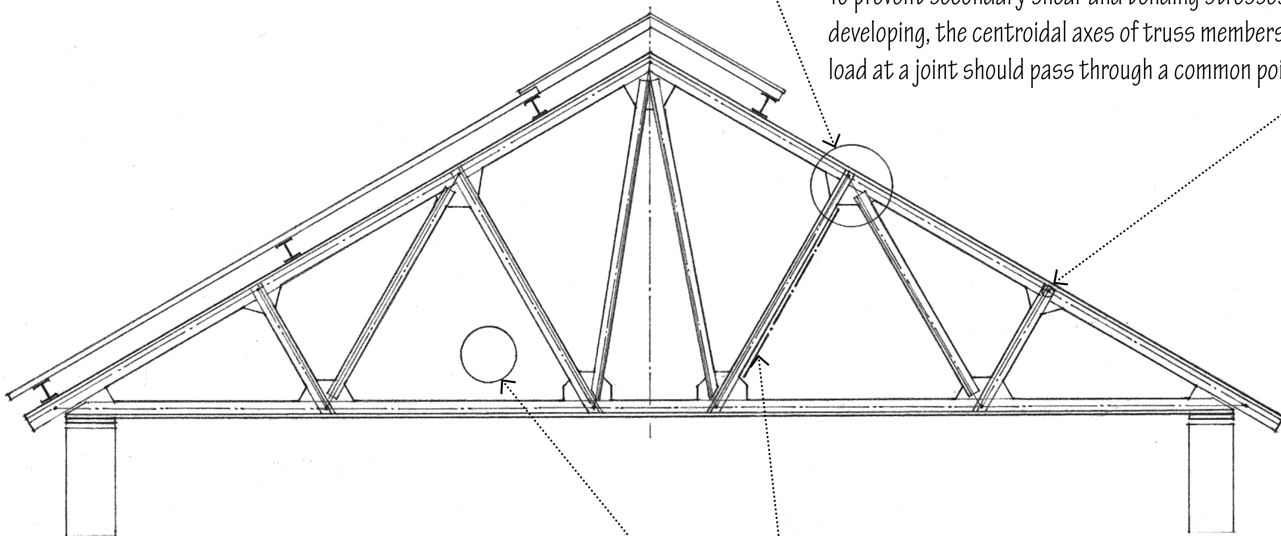


- Sloping roof beams support purlins.
- Beam spacing = purlin span
- Girders support roof beams at ridge and eaves.

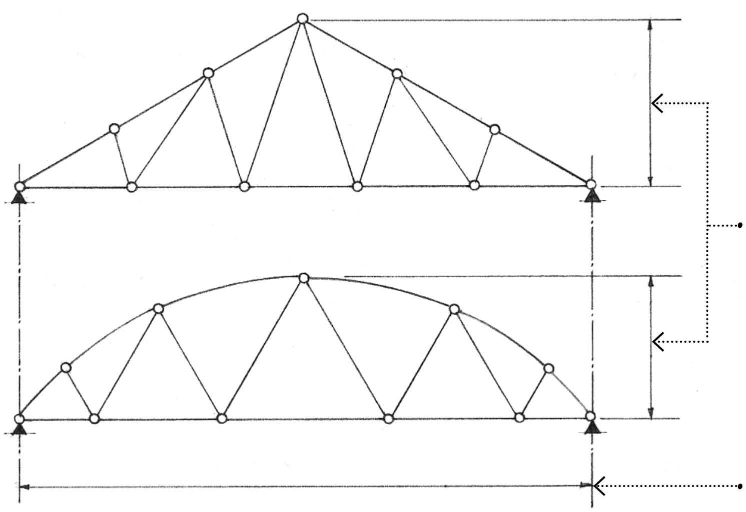
Steel Trusses

Steel trusses are generally fabricated by welding or bolting structural angles and tees together to form the triangulated framework. Because of the slenderness of these truss members, connections usually require the use of steel gusset plates. Heavier steel trusses may utilize wide-flange shapes and structural tubing.

- Members are bolted or welded with gusset plate connectors.
- To prevent secondary shear and bending stresses from developing, the centroidal axes of truss members and the load at a joint should pass through a common point.

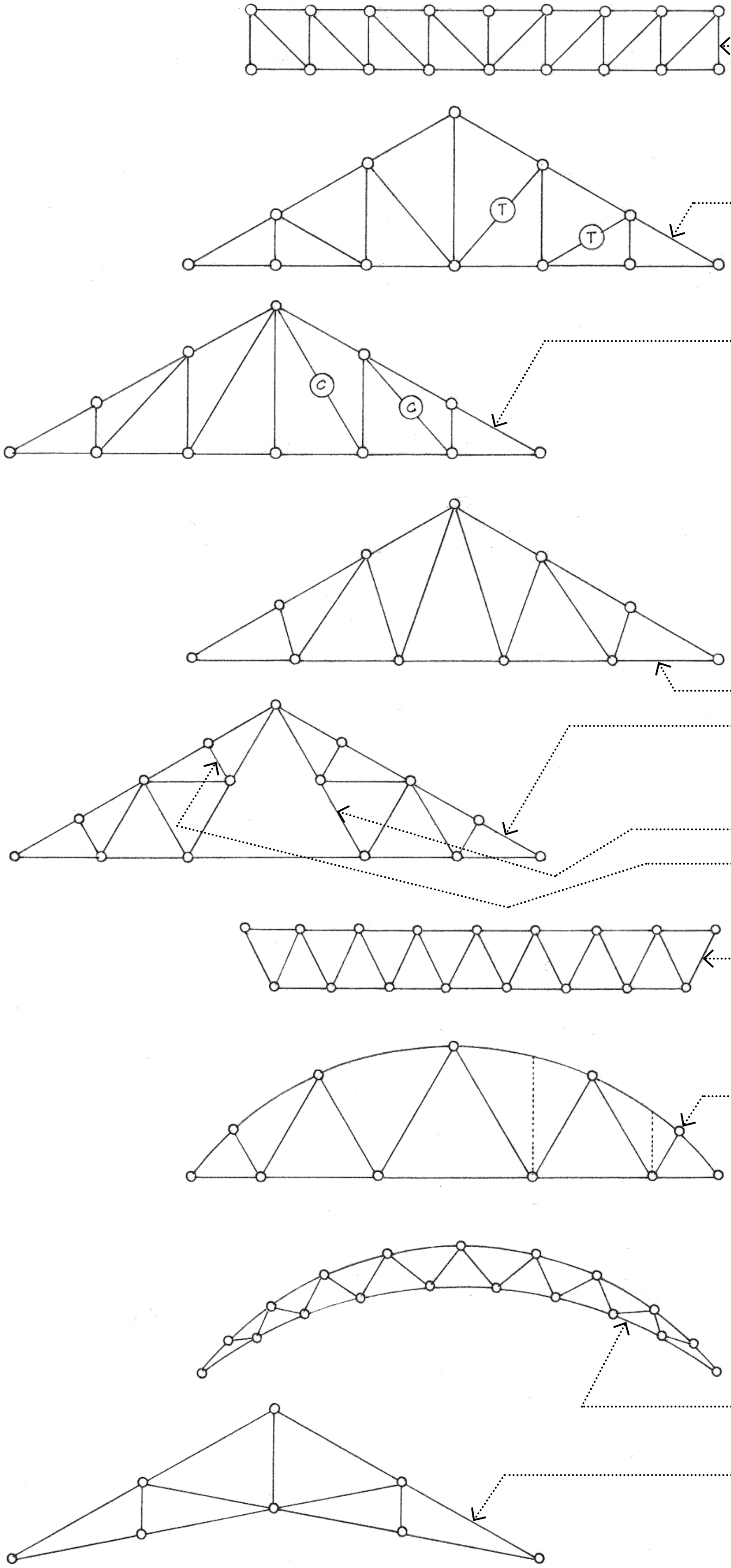


- Trusses require lateral bracing in a direction perpendicular to their planes.
- Mechanical services such as piping, conduit, and ductwork may pass through the web spaces.
- Noncombustible steel construction may be left exposed if at least 20 ft. (6095) above the finish floor.



- The increased depth of trusses allows them to span greater distances than steel beams and girders.
- Span range: 25 ft. to 120 ft. (7 to 36 m)

Truss Types



- Flat trusses have parallel top and bottom chords. Flat trusses are generally not as efficient as pitched or bowstring trusses.

- Pratt trusses have vertical web members in compression and diagonal web members in tension. It is generally more efficient to use a truss type in which the longer web members are loaded in tension.
- Howe trusses have vertical web members in tension and diagonal web members in compression.

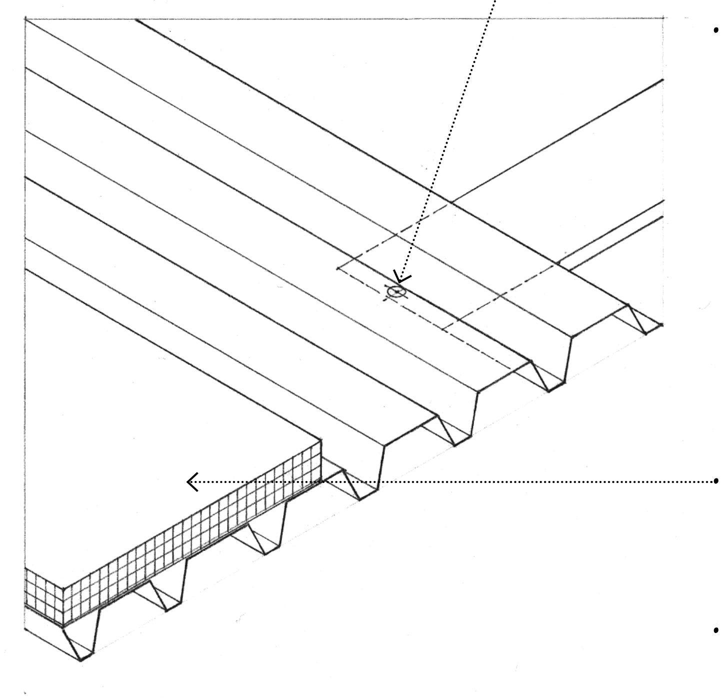
- Belgian trusses have only inclined web members.
- Fink trusses are Belgian trusses having subdiagonals to reduce the length of compression web members toward the centerline of the span.
- Diagonals connect a top to a bottom chord.
- Subdiagonals join a chord with a main diagonal.

- Warren trusses have inclined web members forming a series of equilateral triangles. Vertical web members are sometimes introduced to reduce the panel lengths of the top chord, which is in compression.
- Bowstring trusses have a curved top chord meeting a straight bottom chord at each end.

- Raised-chord trusses have a bottom chord raised substantially above the level of the supports.
- Crescent trusses have both top and bottom chords curving upward from a common point at each side.
- Scissors trusses have tension members extending from the foot of each top chord to an intermediate point on the opposite top chord.

Metal Roof Decking

Metal roof decking is corrugated to increase its stiffness and ability to span across open-web steel joists or more widely spaced steel beams and to serve as a base for thermal insulation and membrane roofing.

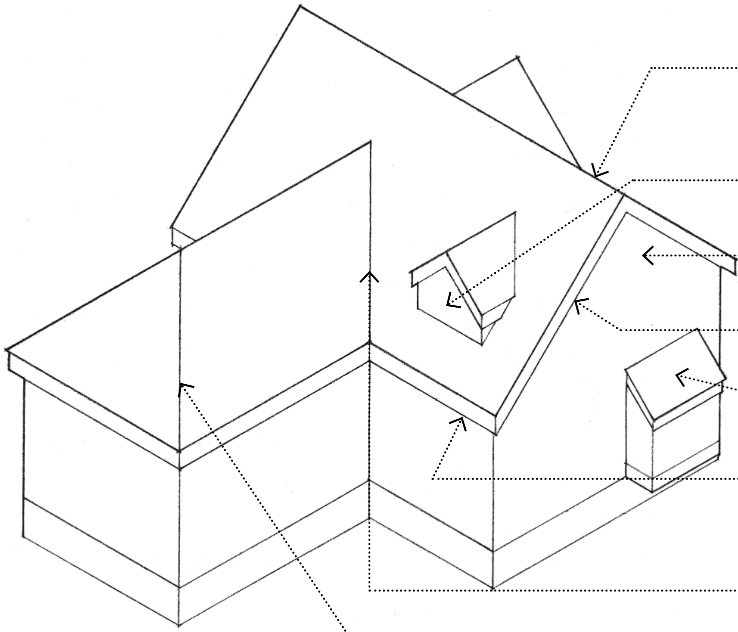


- The decking panels are puddle-welded or mechanically fastened to the supporting steel joists or beams.
- The panels are fastened to each other along their sides with screws, welds, or button punching standing seams.
- If the deck is to serve as a structural diaphragm and transfer lateral loads to shear walls, its entire perimeter must be welded to steel supports. In addition, more stringent requirements for support and side lap fastening may apply.

- Metal roof decking is commonly used without a concrete topping, requiring structural wood or cementitious panels or rigid foam insulation panels to bridge the gaps in the corrugation and provide a smooth, firm surface for the thermal insulation and membrane roofing.
- To provide maximum surface area for the effective adhesion of rigid foam insulation, the top flange should be wide and flat. If the decking has stiffening grooves, the insulation layer may have to be mechanically fastened.

- Metal decking has low-vapor permeance but because of the many discontinuities between the panels, it is not airtight. If an air barrier is required to prevent the migration of moisture vapor into the roofing assembly, a concrete topping can be used. When a lightweight insulating concrete fill is used, the decking may have perforated vents for the release of latent moisture and vapor pressure.

Rafter Framing



Roof Terminology

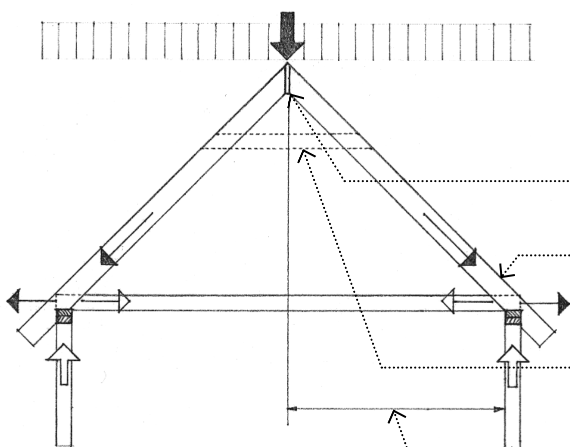
- Ridge is the horizontal line of intersection at the top between two sloping planes of a roof.

- Dormers are projecting structures built out from a sloping roof and housing a vertical window or ventilating louver.
- Gable is the triangular portion of wall enclosing the end of a pitched roof from ridge to eaves.
- Rake is the inclined, usually projecting edge of a sloping roof.

- Shed is a roof having a single slope.

- Eave is the overhanging lower edge of a roof.
- Soffit is the underside of an overhanging roof eave.

- Valley is an intersection of two inclined roof surfaces toward which rainwater flows.
- Hip is the inclined projecting angle formed by the junction of two adjacent sloping sides of a roof.

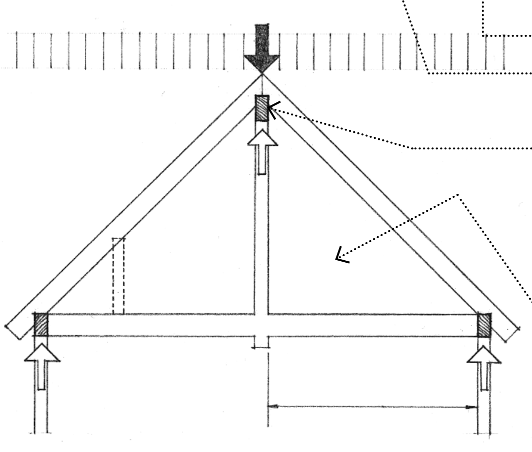


Gable Roofs

Gable roofs slope downward in two parts from a central ridge, so as to form a gable at each end.

- Ridge board is a nonstructural horizontal member to which the upper ends of the rafters are aligned and fastened.
- Common rafters extend from a wall plate to a ridge board or ridge beam and support the sheathing and covering of a roof.

- Collar ties unite two opposing rafters at a point below the ridge, usually in the upper third of the rafter length.
- The ties that resist the outward thrust of the rafters may be designed as ceiling joists supporting only attic loads or as floor joists supporting habitable space.
- Load-bearing wall or beam
- Rafter span



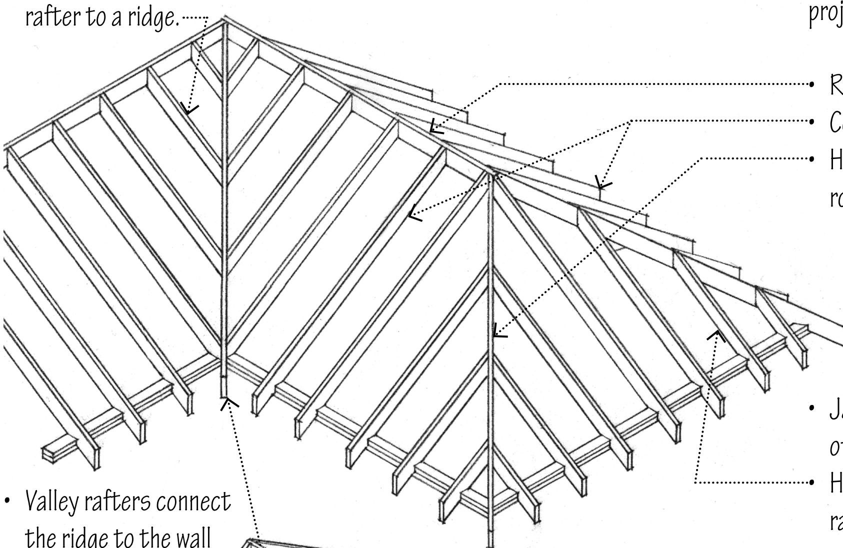
- Ridge beam is a structural horizontal member supporting the upper ends of rafters at the ridge of a roof.
- Rafter ties between the exterior wall or beam supports are not required.

- With sufficient headroom, natural light, and ventilation, attic space may be habitable.

Hip Roofs

Hip roofs have sloping ends and sides meeting at an inclined projecting angle.

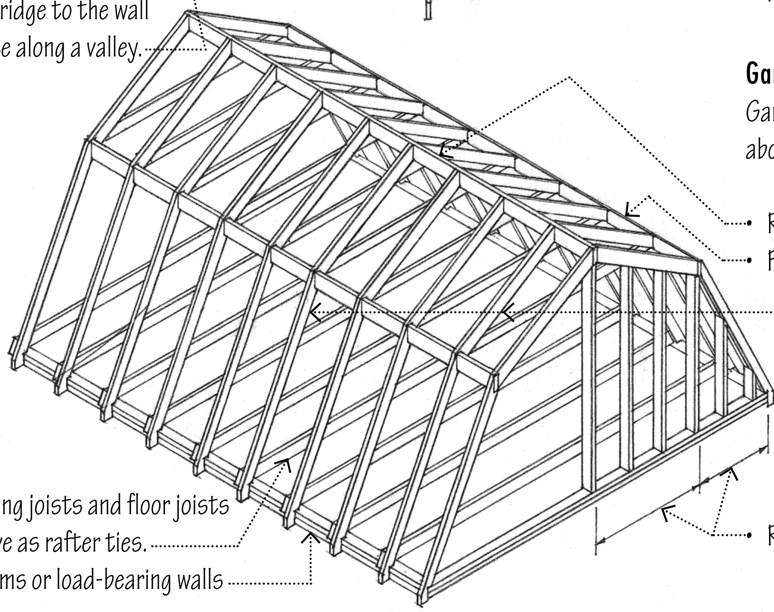
- Valley jacks extend from a valley rafter to a ridge.



- Ridge board
- Common rafters
- Hip rafters form the junction of the sloping sides of a hip roof.
- Jack rafter is any rafter that is shorter than the full length of the roof slope, as one meeting a hip or a valley.
- Hip jacks are jack rafters extending from a wall plate to a hip rafter.
- Valley rafters connect the ridge to the wall plate along a valley.

Gambrel Roofs

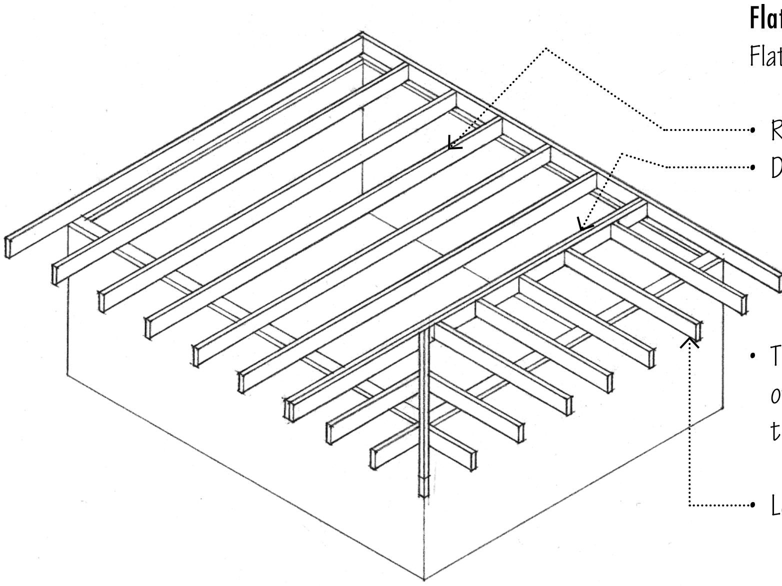
Gambrel roofs are divided on each side into a shallower slope above a steeper one.



- Ridge board
- Purlin
- Common rafters
- Ceiling joists and floor joists serve as rafter ties.
- Beams or load-bearing walls
- Rafter spans

Flat Roofs

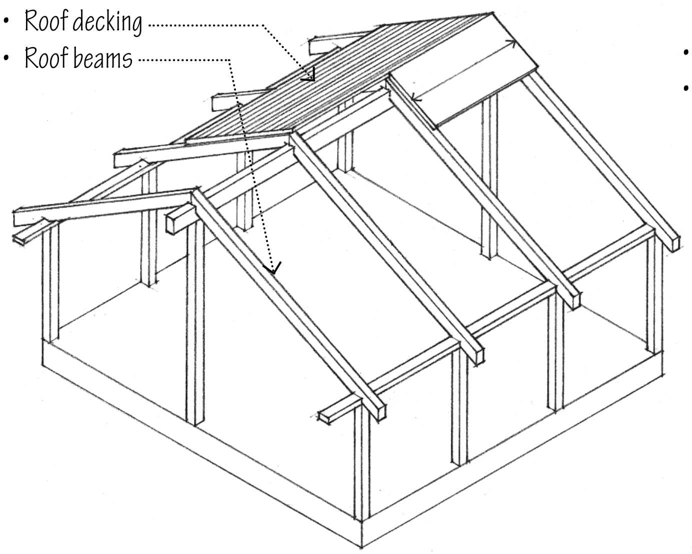
Flat roofs are framed in a manner similar to floor joist framing.



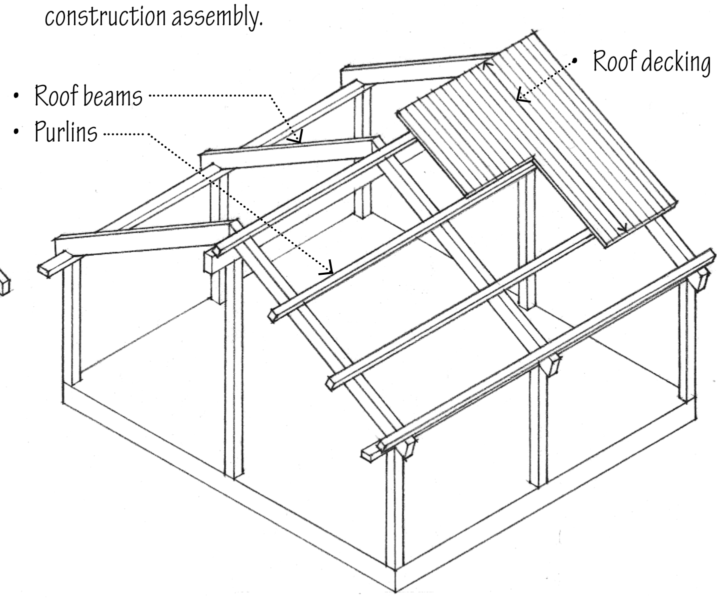
- Roof joists
- Double trimmer joist
- The required roof slope may be achieved by shortening some of the joist supports and sloping the joists, or by tapering the insulating layer of the roof deck.
- Lookout rafters support the roof overhang.

Wood Plank-and-Beam Roofs

There are alternatives for how a plank-and-beam roof structure can be framed, depending on the direction and spacing of the roof beams, the elements used to span the beam spacing, and the overall depth of the construction assembly.

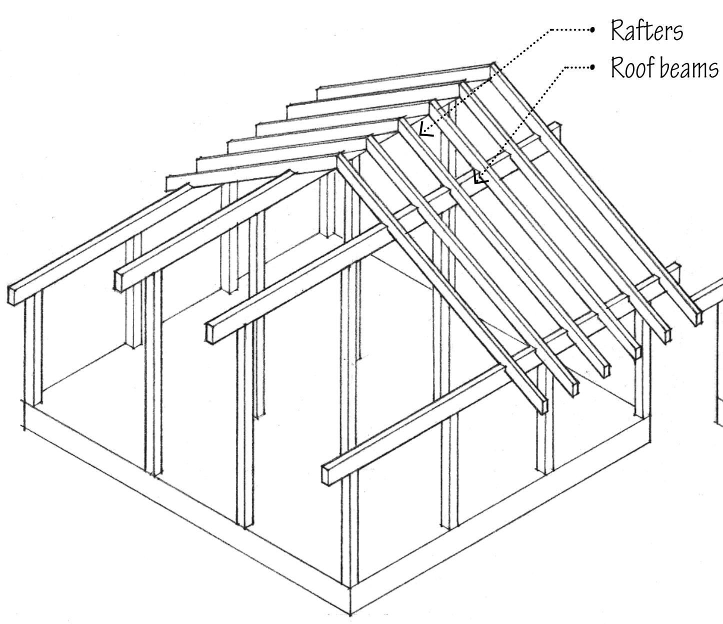


The roof beams may be spaced 4 ft. to 8 ft. (1220 to 2440) o.c. and spanned with solid or glue-laminated wood decking. The beams may be supported by girders, columns, or a reinforced concrete or masonry bearing wall.

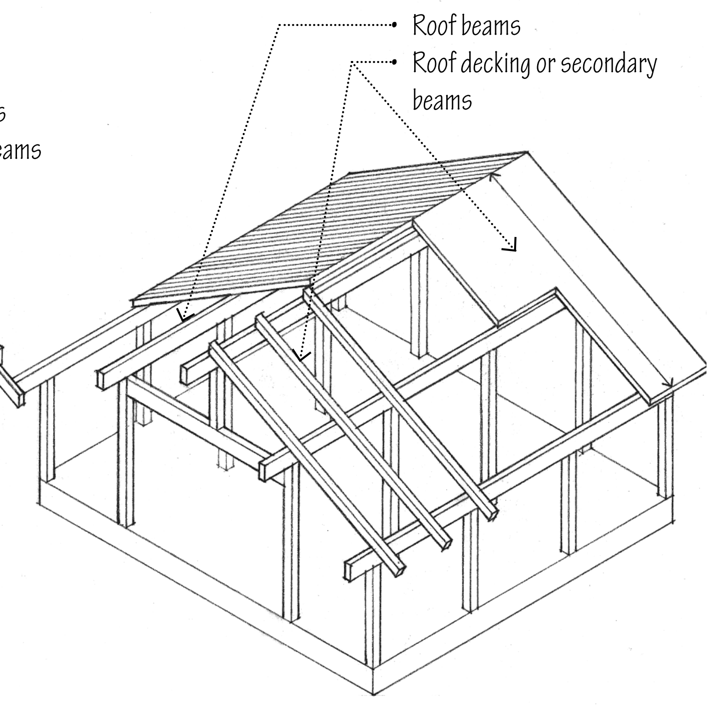


In this two-layer system, the roof beams may be spaced further apart and support a series of purlins. These purlins, in turn, are spanned with wood decking or a rigid, sheet roofing material.

Roof Beams Parallel with Slope



In this example of a two-layer structure, the roof beams support a conventional system of wood rafters.



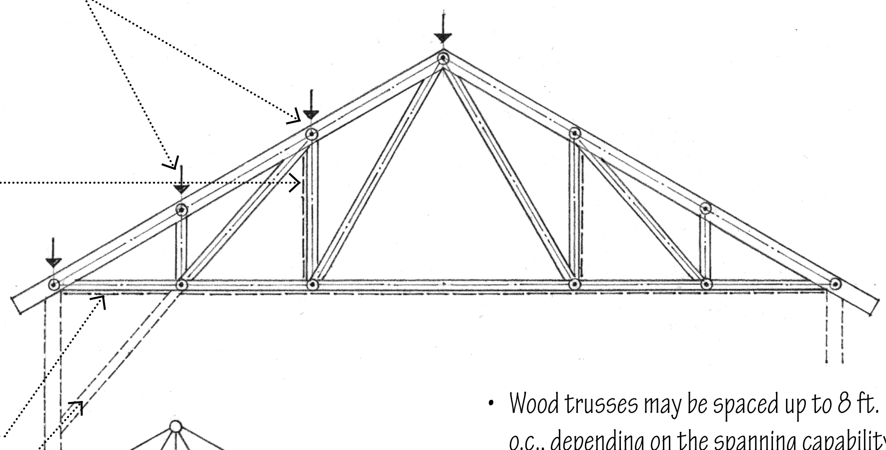
The roof beams may be spaced close enough to be spanned with wood decking. Spaced further apart, the beams can support a series of secondary beams parallel with the slope.

Roof Beams Perpendicular to Slope

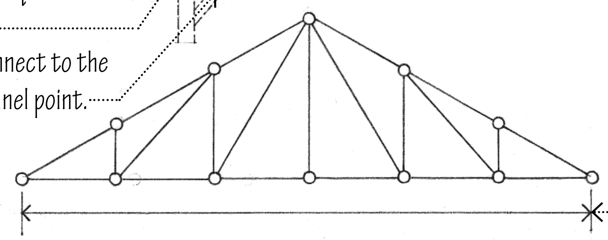
Wood Trusses

In contrast to monoplanar trussed rafters, heavier wood trusses can be assembled by layering multiple members and joining them at the panel points with split-ring connectors. These wood trusses are capable of carrying greater loads than trussed rafters and are spaced further apart.

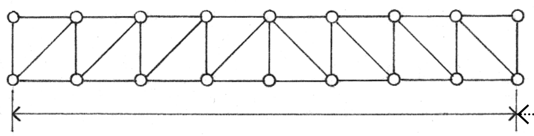
- To avoid additional bending stresses in truss members, loads should be applied at panel points.
- Vertical sway bracing may be required between the top and bottom chords of adjacent trusses to provide resistance against lateral wind and seismic forces.
- Horizontal cross-bracing may be required in the plane of the top or bottom chord if the diaphragm action of the roof framing is not adequate for end-wall forces.
- Any knee bracing should connect to the top or bottom chord at a panel point.



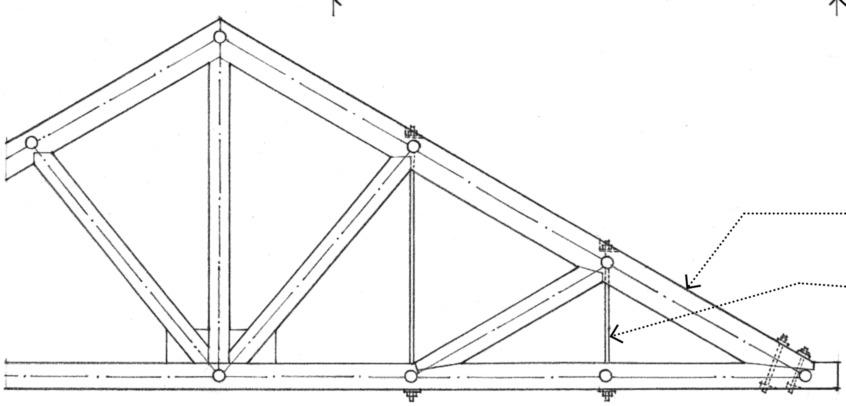
- Wood trusses may be spaced up to 8 ft. (2440) o.c., depending on the spanning capability of the roof decking or planking. When purlins span across the trusses, the truss spacing may be increased up to 20 ft. (6095).



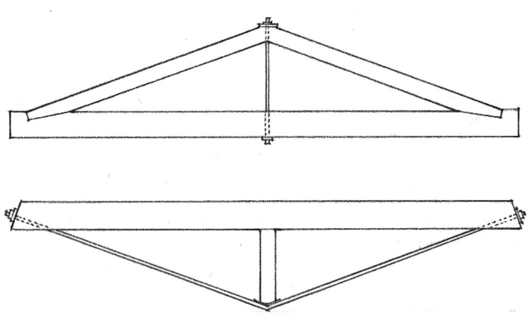
- Span range: 40 ft. to 150 ft. (12 to 45 m)



- Span range: 40 ft. to 110 ft. (12 to 33 m)



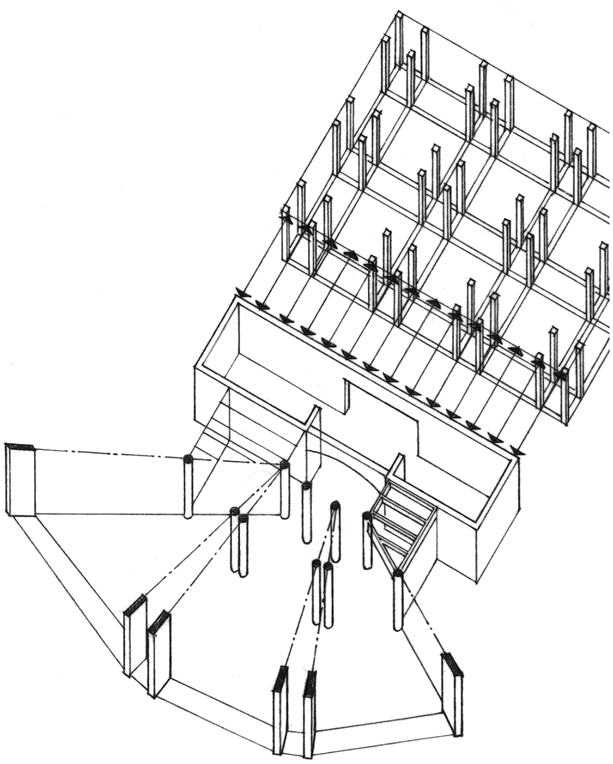
- Composite trusses have timber compression members and steel tension members.
- Truss rods are metal tie rods that serve as tension members in a truss or trussed beam.



- Trussed beams are timber beams stiffened by a combination of diagonal truss rods and either compression struts or suspension rods.

11 Building Structure:

Resisting the Forces That Act against Buildings



How Does an Understanding of Structures Affect Design?

Architecture is sometimes misunderstood as an engineering discipline. Although this is not the case, certain structural knowledge is imperative in creating good design. Understanding basic structural ideas provides the architect with valuable limitations within which the design process can take place. The architect will be able to understand what is possible and impossible, and even more specifically, what is feasible. A working understanding of structures also enables the architect to better communicate and collaborate with the engineers and builders whose responsibility it is to ensure that that the building behaves as it should under the influence of predictable forces. The architect is responsible for coordinating between the various members of the project design team and without a working knowledge of structures this would be impossible.

Structural knowledge also guides design decisions to a great extent. The better an architect understands material behavior, placement and sizing of structural members, and general rules for spans, the better able he or she will be to use structure as a motivating force in generating design ideas. As an example, the architect can use a column grid to define spaces as long as he or she predicts that it will be necessary. The alternative would be to configure spaces only to find out later that columns will have to be placed within them creating awkward, ill-proportioned divisions.

This chapter discusses various structural elements of architecture and the forces that act upon them. It provides an overview of the way architecture resists the various forces that work against it, and where those forces come from.

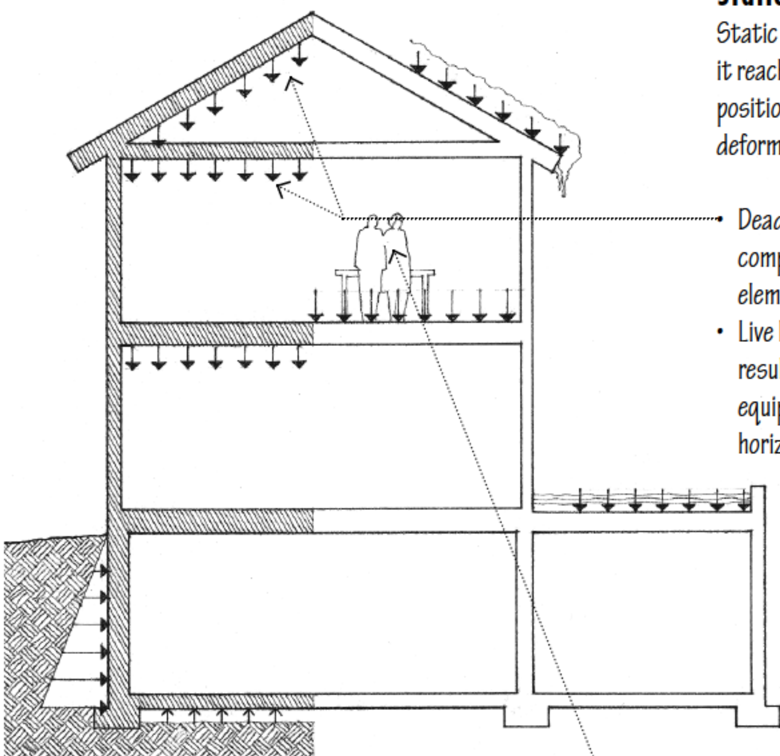
Structural Design

The section focuses on the engineering principles that underlie the requirements and design of structural systems to accommodate anticipated loads, such as the weight of the building, the weight of occupants and materials in the building, and loads imposed by nature such as wind, snow, floods, and earthquakes.

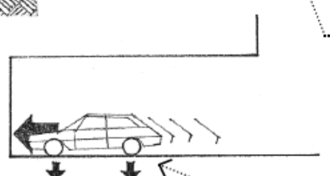
In enclosing space for habitation, the structural system of a building must be able to support two types of loads—static and dynamic.

Static Loads

Static loads are assumed to be applied slowly to a structure until it reaches its peak value without fluctuating rapidly in magnitude or position. Under a static load, a structure responds slowly and its deformation reaches a peak when the static force is maximum.

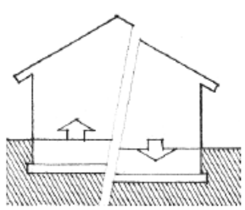


- Dead loads are static loads acting vertically downward on a structure, comprising the self-weight of the structure and the weight of building elements, fixtures, and equipment permanently attached to it.
- Live loads comprise any moving or movable loads on a structure resulting from occupancy, collected snow and water, or moving equipment. A live load typically acts vertically downward but may act horizontally as well to reflect the dynamic nature of a moving load.

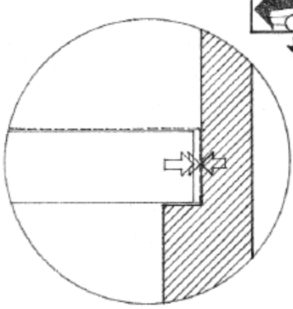


- Occupancy loads result from the weight of people, furniture, stored material, and other similar items in a building. Building codes specify minimum uniformly distributed unit loads for various uses and occupancies.

- Impact loads are kinetic loads of short duration resulting from moving vehicles, equipment, and machinery. Building codes treat this load as a static load, compensating for its dynamic nature by amplifying the static load.



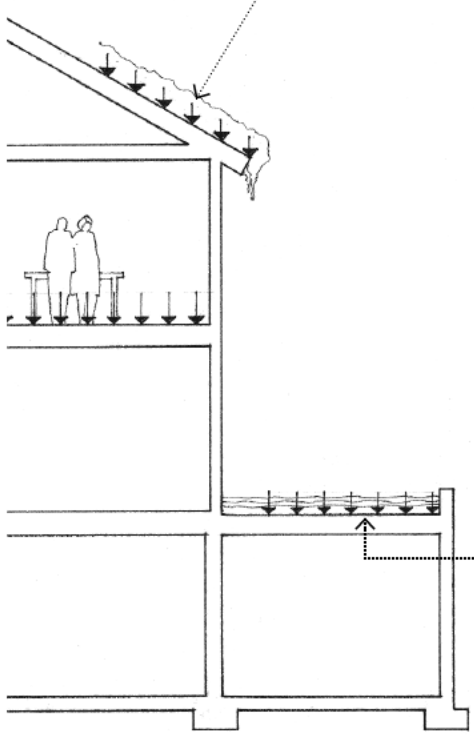
- Settlement loads are imposed on a structure by subsidence of a portion of the supporting soil and the resulting differential settlement of its foundation.
- Water pressure is the hydraulic force groundwater exerts on a foundation system.



- Thermal stresses are the compressive or tensile stresses developed in a material constrained against thermal expansion or contraction.

Roof Loads

Roof loads acting on a sloping surface are to be assumed to act vertically on the horizontal projection of that surface.



Snow Loads

Snow loads are created by the weight of snow accumulating on a roof. Snow loads are determined based upon historical data and are correlated to geographic location and to elevations.

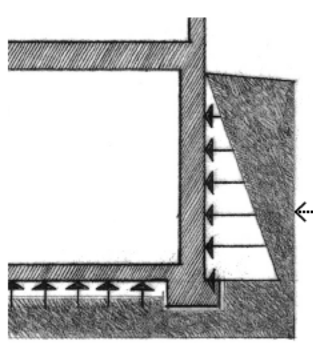
- For example, the snow load in northcentral Kansas, is 25 psf (1.19 kN/m^2).
- In northeast Arizona, the load varies from zero up to the 3000-ft. (914-m) elevation; 5 psf up to the 4500-ft. elevation (0.24 kN/m^2 load up to the 1372 m elevation); 10 psf up to the 5400-ft. elevation (0.48 kN/m^2 load up to the 1645-m elevation) and 15 psf up to the 6300-ft. elevation (0.72 kN/m^2 load up to the 1920 m elevation).
- In heavy snow areas, such as the Sierra Nevada and the Rocky Mountains, the snow load is to be determined by case studies that are based on 50-year recurrence data and must be approved by the building official.

Rain Loads

Roofs are to be designed to accommodate the load of accumulated water when roof drains are clogged. Roofs with a slope less than a $^1/_4$ unit vertical in 12 units horizontal (2% slope) must be analyzed to determine if ponding will result in progressive deformation of the roof members, leading to potential roof instability or failure. The anticipated depth of water is based on the difference in elevation between the normal roof drain system and the outlet of the overflow system.

Flood Loads

In flood hazard areas all new buildings, as well as major improvements or reconstruction projects, must be designed to resist the effects of flood hazards or flood loads. Determination of whether a building falls under this requirement is based on locally adopted flood-hazard maps. These identify the anticipated flooding areas and elevations of flood waters for given anticipated return periods such as 50 or 100 years. The elevation and location of the building site must be compared to the flood-hazard maps to determine if this section is applicable.

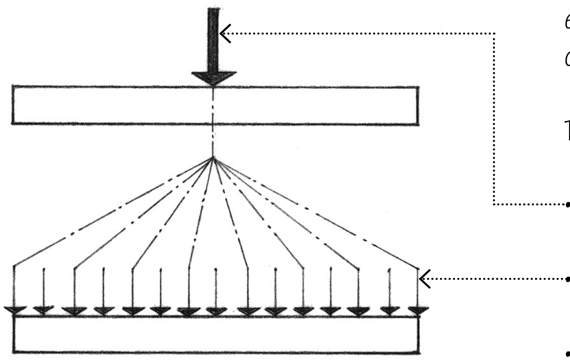


Soil Lateral Load

Basement walls and retaining walls must be able to resist lateral loads imposed by the ground pressure behind the walls. These walls are to be designed to be stable against overturning, sliding, excessive foundation pressure, and water uplift. The soil loads range from 30 psf per foot of depth (4.7 kPa/m) for gravels to 60 psf per foot of depth (9.4 kPa/m) for relatively dense inorganic clay soils.

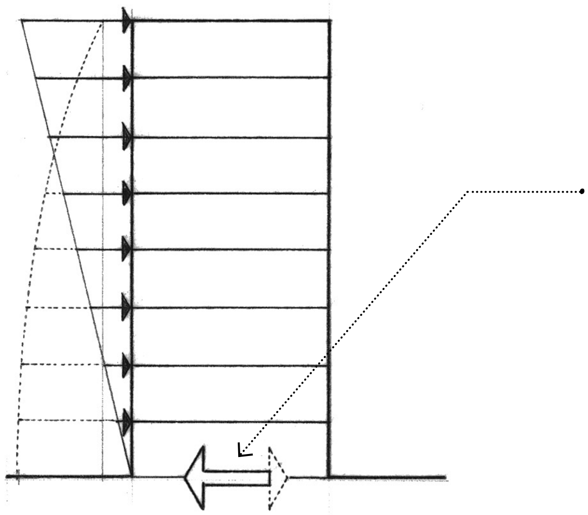
Load Combinations

Various combinations of dead loads, live loads, seismic loads, and wind loads are to be applied in the design of structural systems when their combined effect can be reasonably expected to be less than the sum of their separate actions. The load factors for each combination depend on the type of analysis used. Various combinations of loading are to be examined, and the design is to resist the most critical effects of the combinations specified.

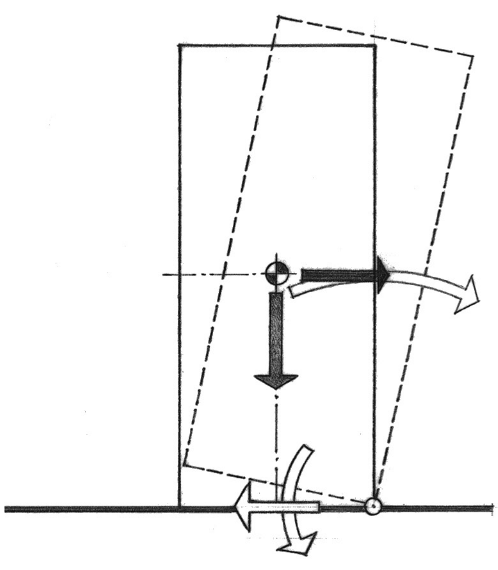


These loads can act on a structure in several ways:

- A concentrated load is a load acting on a very small area or particular point of a supporting structural element
- A distributed load is a load extending over the length or area of the supporting structural element
- A uniformly distributed load a distributed load of uniform magnitude



- A lateral load is a load acting horizontally on a structure, such as a wind or earthquake load

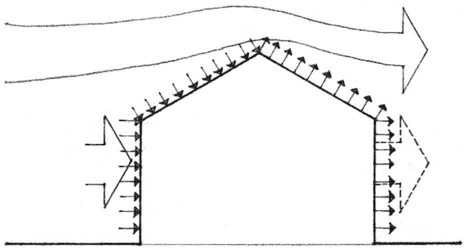


Dynamic Loads

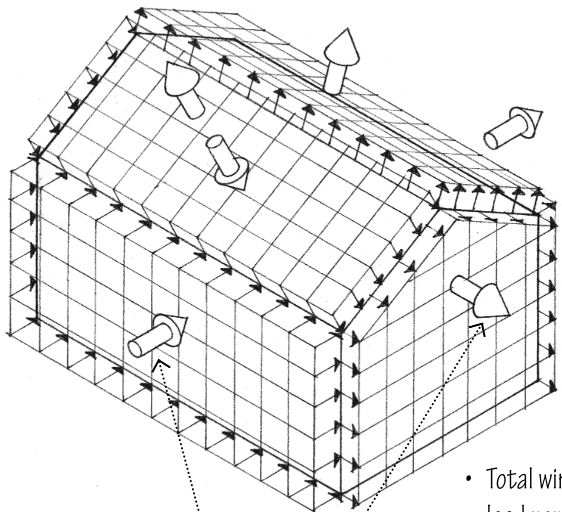
Dynamic loads are applied suddenly to a structure, often with rapid changes in magnitude and point of application. Under a dynamic load, a structure develops inertial forces in relation to its mass, and its maximum deformation does not necessarily correspond to the maximum magnitude of the applied force.

The two major types of dynamic loads are wind loads and earthquake loads.

Wind Loads

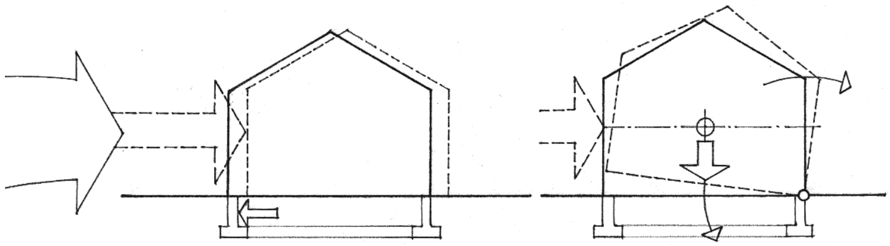


Buildings and portions of buildings are to be designed to withstand, at a minimum, the wind loads. The wind is assumed to come from any horizontal direction, and no reduction is to be taken for the effect of shielding by other structures. This is in keeping with the principle that building code requirements apply to the building in question and is affected neither positively nor negatively by adjacent buildings. There are, however, portions of the building code where adjacent site and topographic conditions may affect wind loads.



- Total wind loads are determined by taking the product of the wind load per square foot multiplied by the area of building or structure projected on a vertical plane normal to the wind direction.

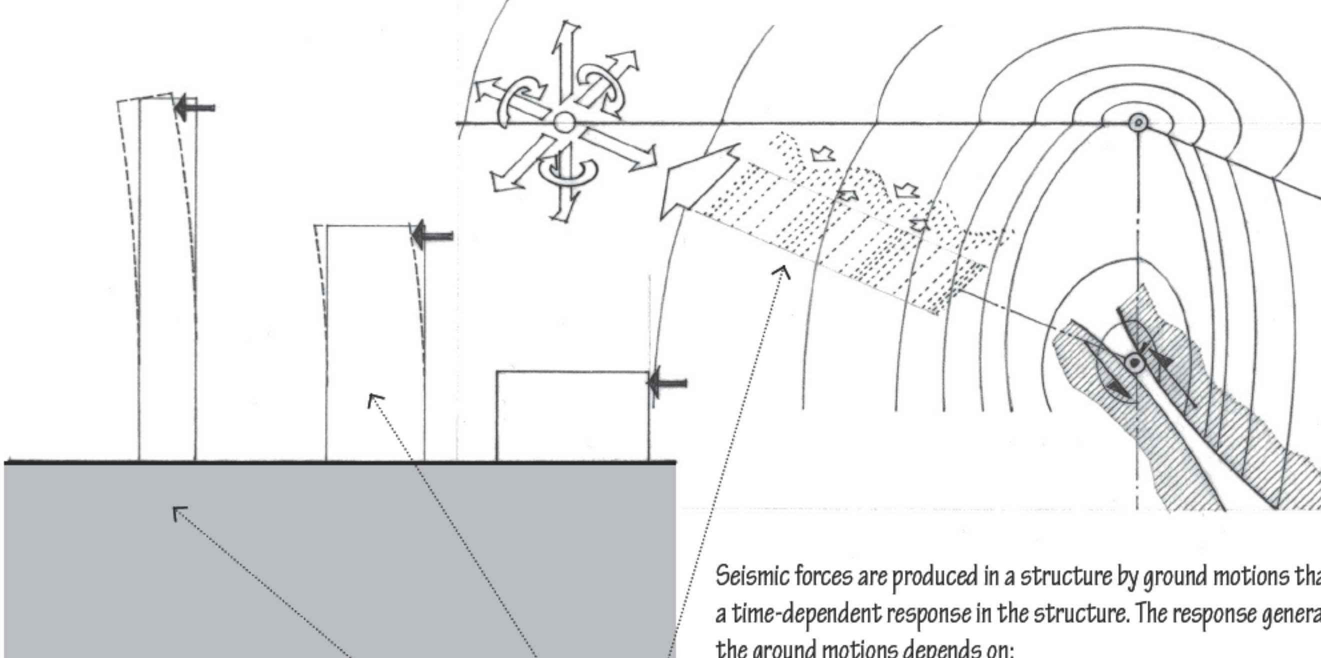
- Wind is to be assumed to come from any horizontal direction, and wind pressures are to be assumed to act normal to the surface considered.
- Because wind can create suction as well as pressure effects on a building, the force is to be resisted in either direction normal to the surface.



- Structural members and systems, as well as building cladding, must be anchored to resist overturning, uplift, or sliding caused by wind forces. Continuous load paths for these forces are to be provided to the foundation.

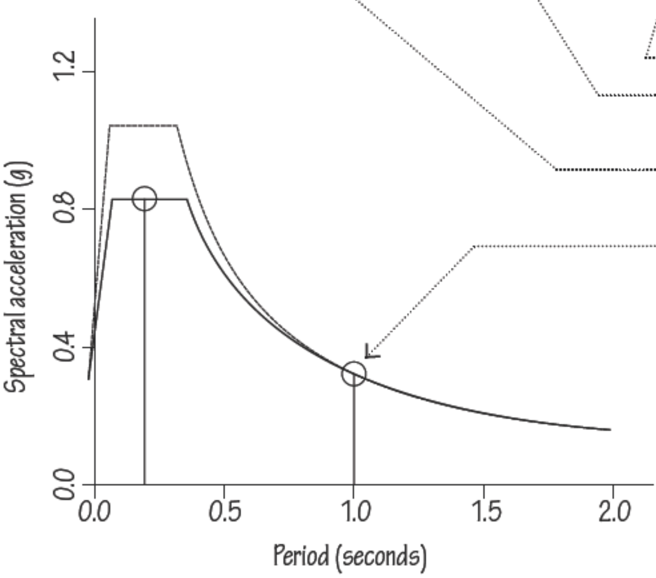
Earthquake Loads

Earthquake design must be investigated for every structure and included to varying degrees based on the location of the building and the anticipated seismicity of the location. Earthquake design can be quite complex and involve detailed calculations. Certain basic types of structure, notably those wood-frame residences and light commercial buildings using conventional light-frame construction, are deemed to comply with the seismic requirements. Other more complex buildings must undergo seismic analysis. This analysis takes into account several basic factors. While we will not go into the design calculation bases in detail, it is worth understanding the basic criteria that are to be addressed by seismic analysis and design.



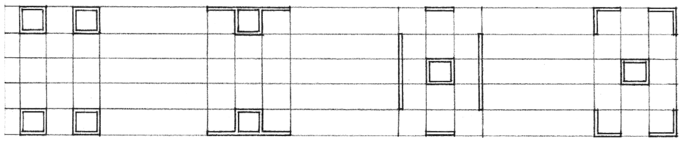
Seismic forces are produced in a structure by ground motions that cause a time-dependent response in the structure. The response generated by the ground motions depends on:

- The magnitude, duration, and harmonic content of the ground motions
- The dynamic properties of the structure (size, configuration, and stiffness)
- The type and characteristics of the soil supporting the structure



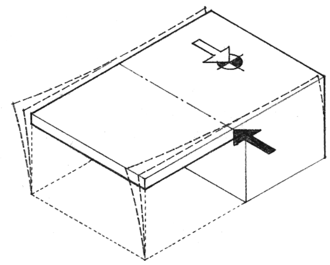
The magnitude of earthquake ground motions at a specific site depends on the proximity of the site to the earthquake source, the site's soil characteristics and the attenuation of the peak acceleration. The dynamic response of a structure to earthquake ground motions can be represented by a graph of spectral response acceleration versus period.

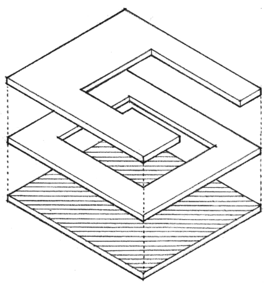
All structures require lateral-force-resisting and vertical-force-resisting systems having adequate strength, stiffness, and energy dissipation capacity to withstand the anticipated or design earthquake ground motions.

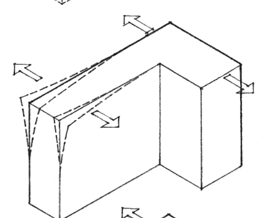


- Symmetrical layouts

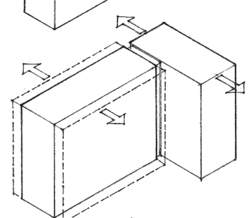
- Seismic ground motions are assumed to occur along any horizontal direction of a structure.
- Continuous load paths are required to transfer forces induced by earthquake ground motions from points of application to points of resistance.



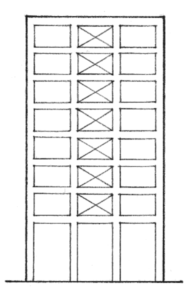


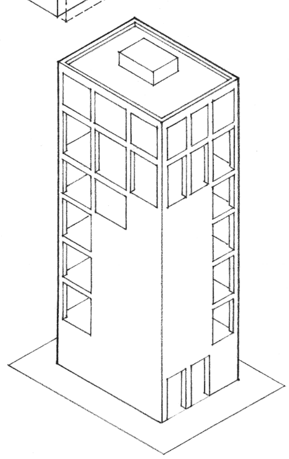


- Asymmetrical arrangements

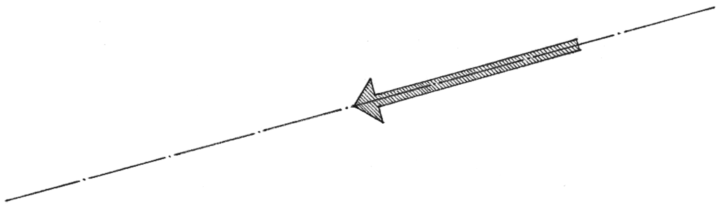


- To avoid destructive torsional effects, structures subject to lateral forces should be arranged and braced symmetrically with centers of mass and resistance as coincident as possible. The asymmetrical layout of irregular structures generally requires dynamic analysis in order to determine the torsional effects of lateral forces.

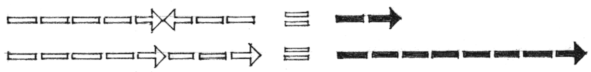




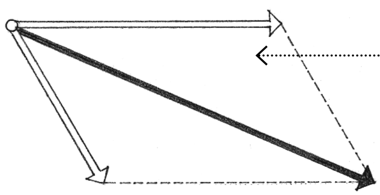
Structural Forces

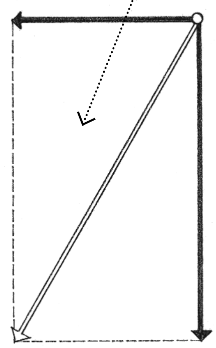


A force is any influence that produces a change in the shape or movement of a body. It is considered to be a vector quantity possessing both magnitude and direction, represented by an arrow whose length is proportional to the magnitude and whose orientation in space represents the direction. A single force acting on a rigid body may be regarded as acting anywhere along its line of action without altering the external effect of the force. Two or more forces may be related in the following ways:

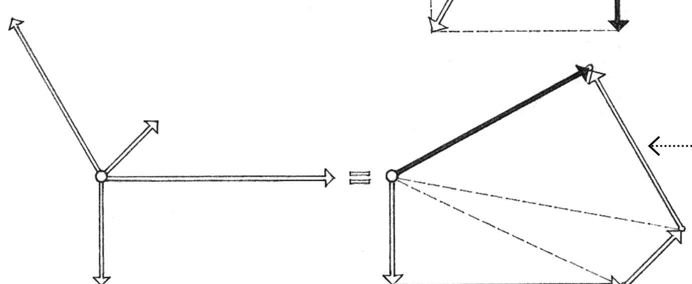


- Collinear forces occur along a straight line, the vector sum of which is the algebraic sum of the magnitudes of the forces, acting along the same line of action.

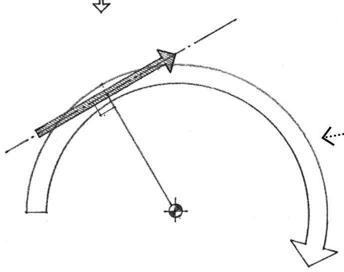


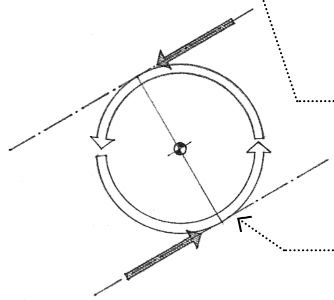


- Concurrent forces have lines of action intersecting at a common point, the vector sum of which is equivalent to and produces the same effect on a rigid body as the application of the vectors of the several forces.
- The parallelogram law states that the vector sum or resultant of two concurrent forces can be described by the diagonal of a parallelogram having adjacent sides that represent the two force vectors being added.
- In a similar manner, any single force can be resolved into two or more concurrent forces having a net effect on a rigid body equivalent to that of the initial force. For convenience in structural analysis, these are usually the rectangular or Cartesian components of the initial force.



- The polygon method is a graphic technique for finding the vector sum of a coplanar system of several concurrent forces by drawing to scale each force vector in succession, with the tail of each at the head of the one preceding it, and completing the polygon with a vector that represents the resultant force, extending from the tail of the first to the head of the last vector.

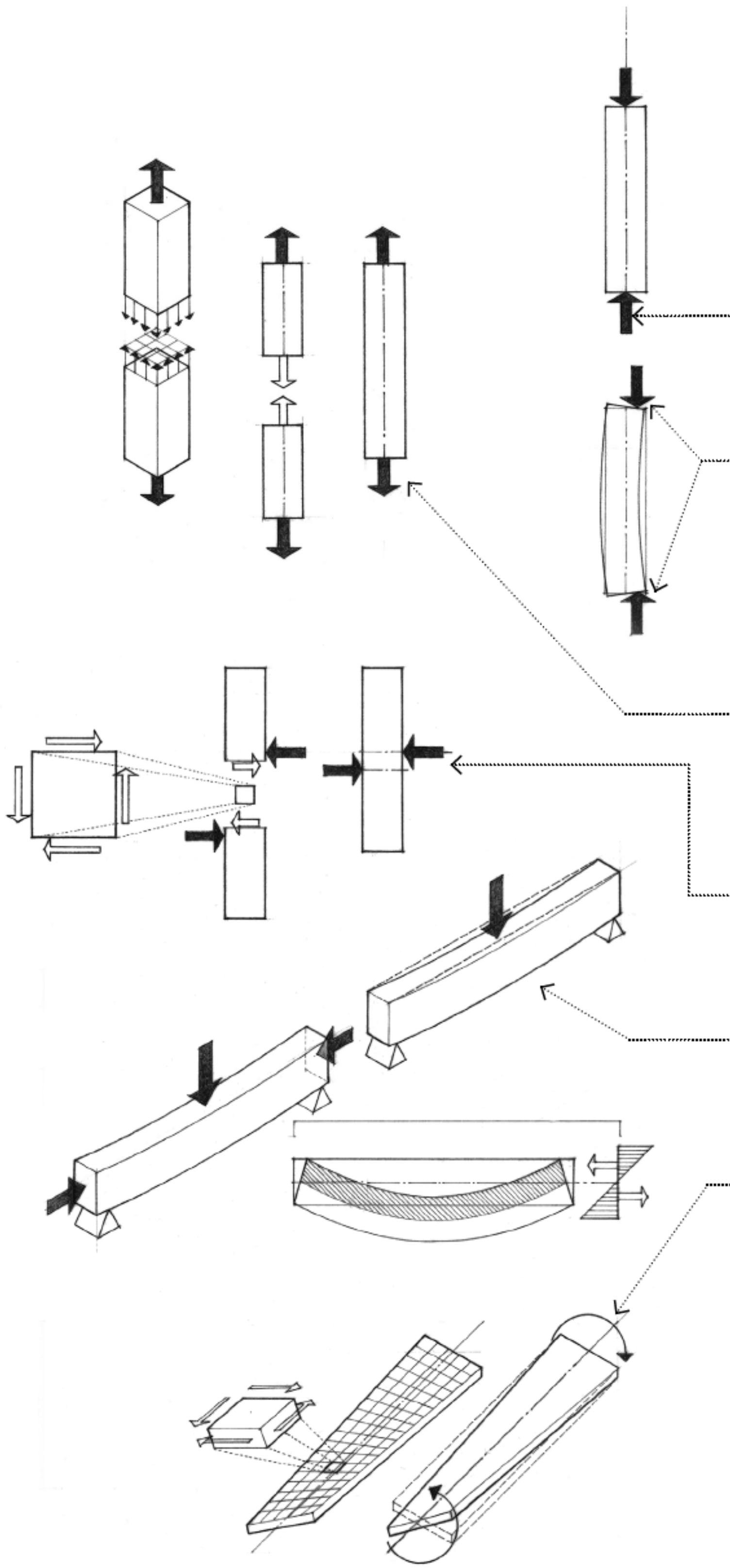




- Nonconcurrent forces have lines of action that do not intersect at a common point, the vector sum of which is a single force that would cause the same translation and rotation of a body as the set of original forces.
- A moment is the tendency of a force to produce rotation of a body about a point or line, equal in magnitude to the product of the force and the moment arm and acting in a clockwise or counterclockwise direction.
- A couple is a force system of two equal, parallel forces acting in opposite directions and tending to produce rotation but not translation. The moment of a couple is equal in magnitude to the product of one of the forces and the perpendicular distance between the two forces.

Forces

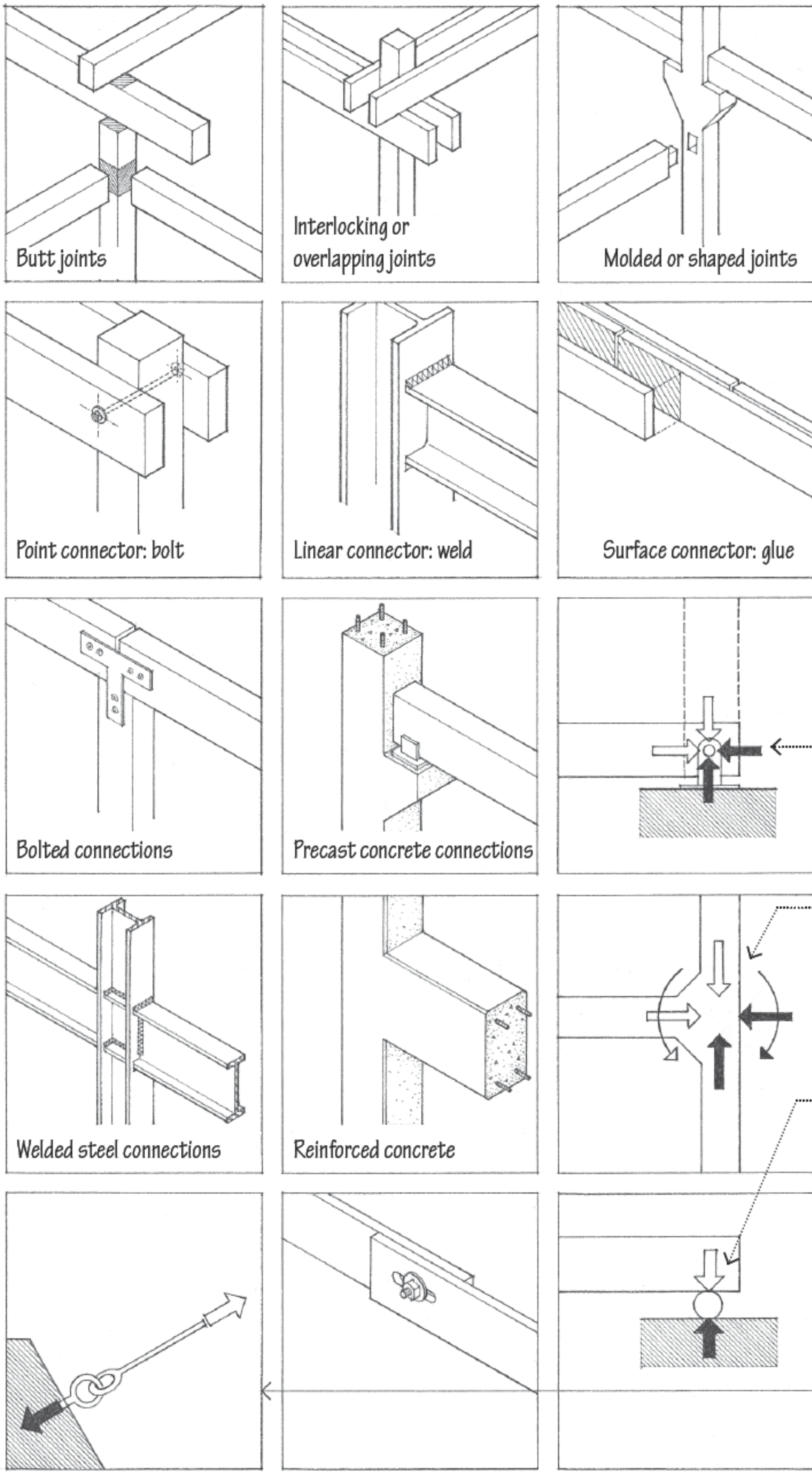
Forces are classified based upon the way in which they act on a structural element. Different materials resist forces to various degrees, depending upon the way in which that force is applied to the element, as well as the proportional characteristics of the element. Resistance of an element can be described by stress and strain. Stress refers to the resistance of an element to forces applied to it and is measured in units of force to units of cross-sectional area of the element. Strain refers to the deformation of a body caused by forces applied to it and is measured by the ratio of change in size or shape compared to the original size or shape of the element. Forces act upon structural elements in the following ways:



- An axial force is a tensile or compressive force acting along the longitudinal axis of a structural member and at the centroid of the cross section, producing axial stress without bending, torsion, or shear. Also called axial load.
- An eccentric force is a force applied parallel to the longitudinal axis of a structural member but not to the centroid of the cross section, producing bending and an uneven distribution of stresses in the section. Also called eccentric load.

Forces affect structural elements in the following ways:

- Tension is the act of stretching or state of being pulled apart, resulting in the elongation of an elastic body.
- Compression is the act of shortening or state of being pushed together, resulting in a reduction in size or volume of an elastic body.
- Shear is the lateral deformation produced in a body by an external force that causes one part of the body to slide relative to an adjacent part in a direction parallel to their plane of contact.
- Bending is the bowing of an elastic body as an external force is applied transversely to its length. Bending is the structural mechanism that enables a load to be channeled in a direction perpendicular to its application.
- Torque is the moment of a force system that causes or tends to cause rotation or torsion.



Joints and Connections

The manner in which forces are transferred from one structural element to the next and how a structural system performs as a whole depend to a great extent on the types of joints and connections used. Structural elements can be joined to each other in three ways. Butt joints allow one of the elements to be continuous and usually require a third mediating element to make the connection. Overlapping joints allow all of the connected elements to bypass each other and be continuous across the joint. The joining elements can also be molded or shaped to form a structural connection.

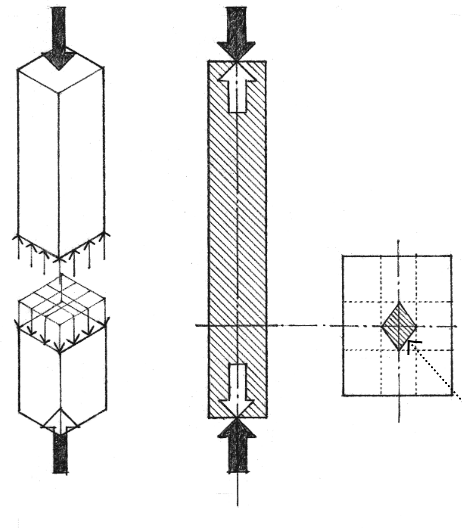
The connectors used to join the structural elements may be in the form of a point, a line, or a surface. While linear and surface types of connectors resist rotation, point connectors do not unless a series of them is distributed across a large surface area.

- Pinned joints theoretically allow rotation but resist translation in any direction.
- Rigid or fixed joints maintain the angular relationship between the joined elements, restrain rotation and translation in any direction, and provide both force and moment resistance.
- Roller joints allow rotation but resist translation in a direction perpendicular into or away from their faces. They are not employed in building construction as often as pinned or fixed connections, but they are useful when a joint must allow expansion and contraction of a structural element to occur.
- A cable anchorage allows rotation but resists translation only in the direction of the cable.

Structural Elements

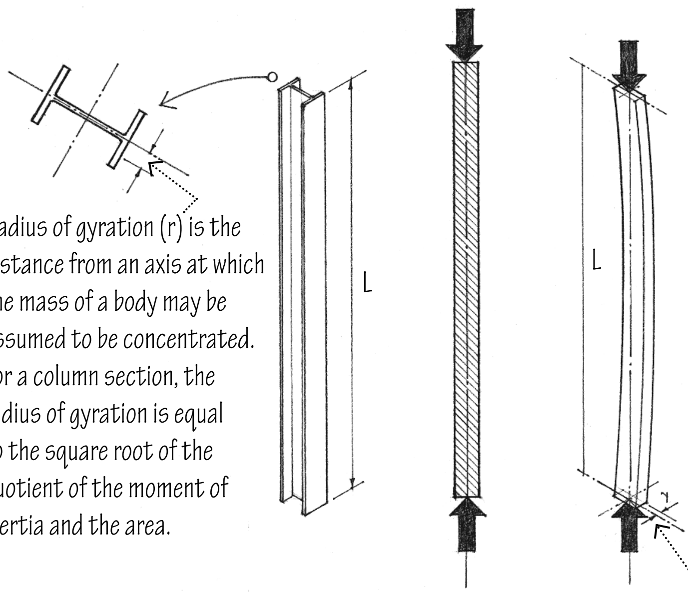
Columns

Columns are rigid, relatively slender structural members designed primarily to support axial compressive loads applied to the ends of the members. Relatively short, thick columns are subject to failure by crushing rather than by buckling. Failure occurs when the direct stress from an axial load exceeds the compressive strength of the material available in the cross section. An eccentric load, however, can produce bending and result in an uneven stress distribution in the section.

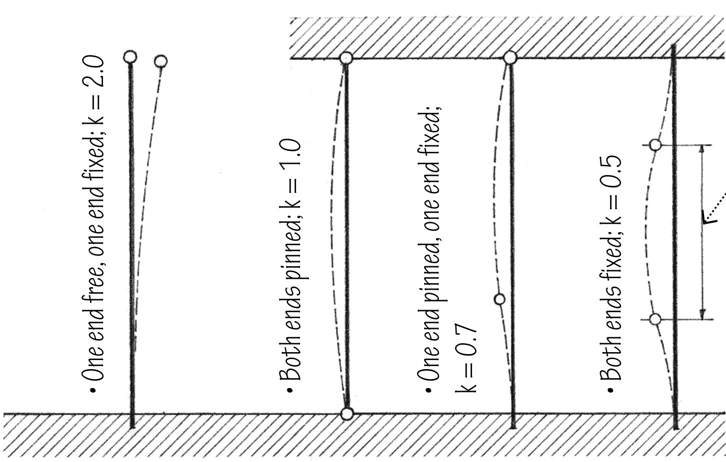


- External forces create internal stresses within structural elements.
- Kern area is the central area of any horizontal section of a column or wall within which the resultant of all compressive loads must pass if only compressive stresses are to be present in the section. A compressive load applied beyond this area will cause tensile stresses to develop in the section.

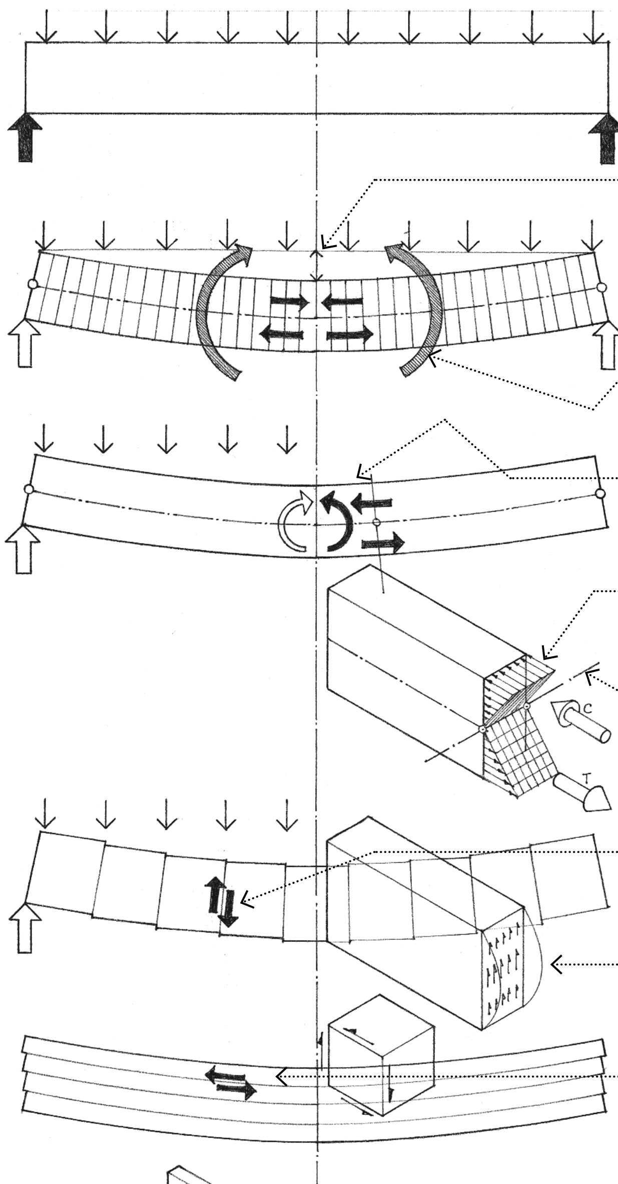
Long, slender columns are subject to failure by buckling rather than by crushing. Buckling is the sudden lateral or torsional instability of a slender structural member induced by the action of an axial load before the yield stress of the material is reached. Under a buckling load, a column begins to deflect laterally and cannot generate the internal forces necessary to restore its original linear condition. Any additional loading would cause the column to deflect further until collapse occurs in bending. The higher the slenderness ratio of a column, the lower is the critical stress that will cause it to buckle. A primary objective in the design of a column is to reduce its slenderness ratio by shortening its effective length or maximizing the radius of gyration of its cross section.



- Radius of gyration (r) is the distance from an axis at which the mass of a body may be assumed to be concentrated. For a column section, the radius of gyration is equal to the square root of the quotient of the moment of inertia and the area.
- The slenderness ratio of a column is the ratio of its effective length (L) to its least radius of gyration (r). For asymmetrical column sections, therefore, buckling will tend to occur about the weaker axis or in the direction of the least dimension.



- Effective length is the distance between inflection points in a column subject to buckling. When this portion of a column buckles, the entire column fails.
- The effective length factor (k) is a coefficient for modifying the actual length of a column according to its end conditions in order to determine its effective length. For example, fixing both ends of a long column reduces its effective length by half and increases its load-carrying capacity by a factor of 4.

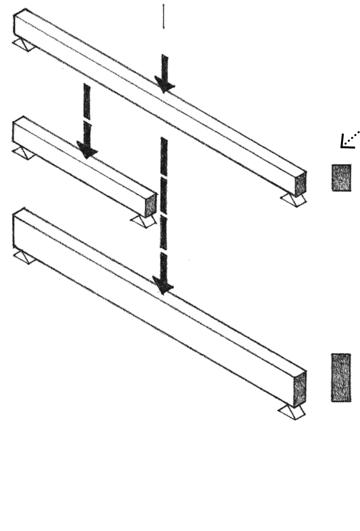


Beams

Beams are rigid structural members designed to carry and transfer transverse loads across space to supporting elements. The nonconcurrent pattern of forces subjects a beam to bending and deflection, which must be resisted by the internal strength of the material.

- Deflection is the perpendicular distance a spanning member deviates from a true course under transverse loading, increasing with load and span, and decreasing with an increase in the moment of inertia of the section or the modulus of elasticity of the material.
- Bending moment is an external moment tending to cause part of a structure to rotate or bend, equal to the algebraic sum of the moments about the neutral axis of the section under consideration.
- Resisting moment is an internal moment equal and opposite to a bending moment, generated by a force couple to maintain equilibrium of the section being considered.
- Bending stress is a combination of compressive and tension stresses developed at a cross section of a structural member to resist a transverse force, having a maximum value at the surface furthest from the neutral axis.
- The neutral axis is an imaginary line passing through the centroid of the cross section of a beam or other member subject to bending, along which no bending stresses occur.

- Transverse shear occurs at a cross section of a beam or other member subject to bending, equal to the algebraic sum of transverse forces on one side of the section.
- Vertical shearing stress develops to resist transverse shear, having a maximum value at the neutral axis and decreasing nonlinearly toward the outer faces.
- Horizontal or longitudinal shearing stress develops to prevent slippage along horizontal planes of a beam under transverse loading, equal at any point to the vertical shearing stress at that point.

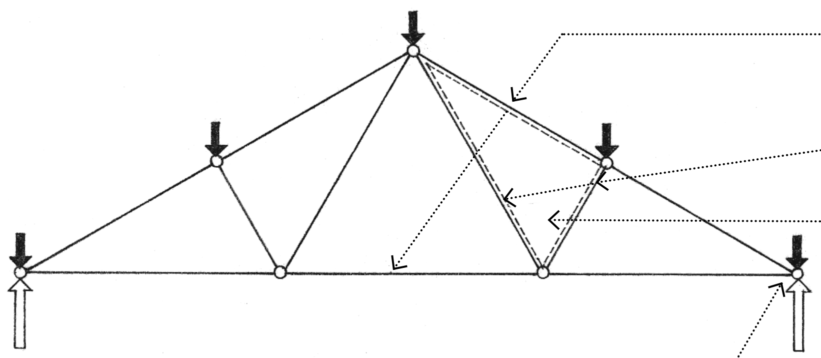


The efficiency of a beam is increased by configuring the cross section to provide the required moment of inertia or section modulus with the smallest possible area, usually by making the section deep with most of the material at the extremities where the maximum bending stresses occur. For example, while halving a beam span or doubling its width reduces the bending stresses by a factor of 2, doubling the depth reduces the bending stresses by a factor of 4.

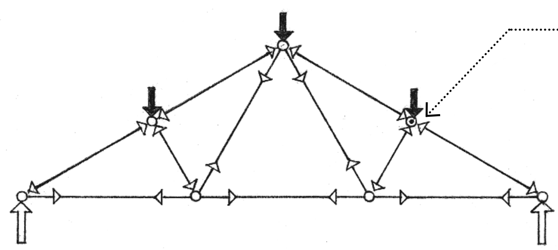
- Moment of inertia is the sum of the products of each element of an area and the square of its distance from a coplanar axis of rotation. It is a geometric property that indicates how the cross-sectional area of a structural member is distributed and does not reflect the intrinsic physical properties of a material.
- Section modulus is a geometric property of a cross section, defined as the moment of inertia of the section divided by the distance from the neutral axis to the most remote surface.

Trusses

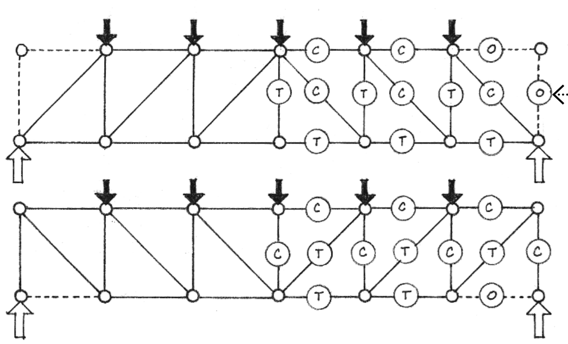
A truss is a structural frame based on the geometric rigidity of the triangle and composed of linear members subject only to axial tension or compression.



- Top and bottom chords are the principal members of a truss extending from end to end and connected by web members.
- Web is the integral system of members connecting the upper and lower chords of a truss.
- Panel refers to any of the spaces within the web of a truss between any two panel points on a chord and a corresponding joint or pair of joints on an opposite chord.
- Heel is the lower, supported end of a truss.

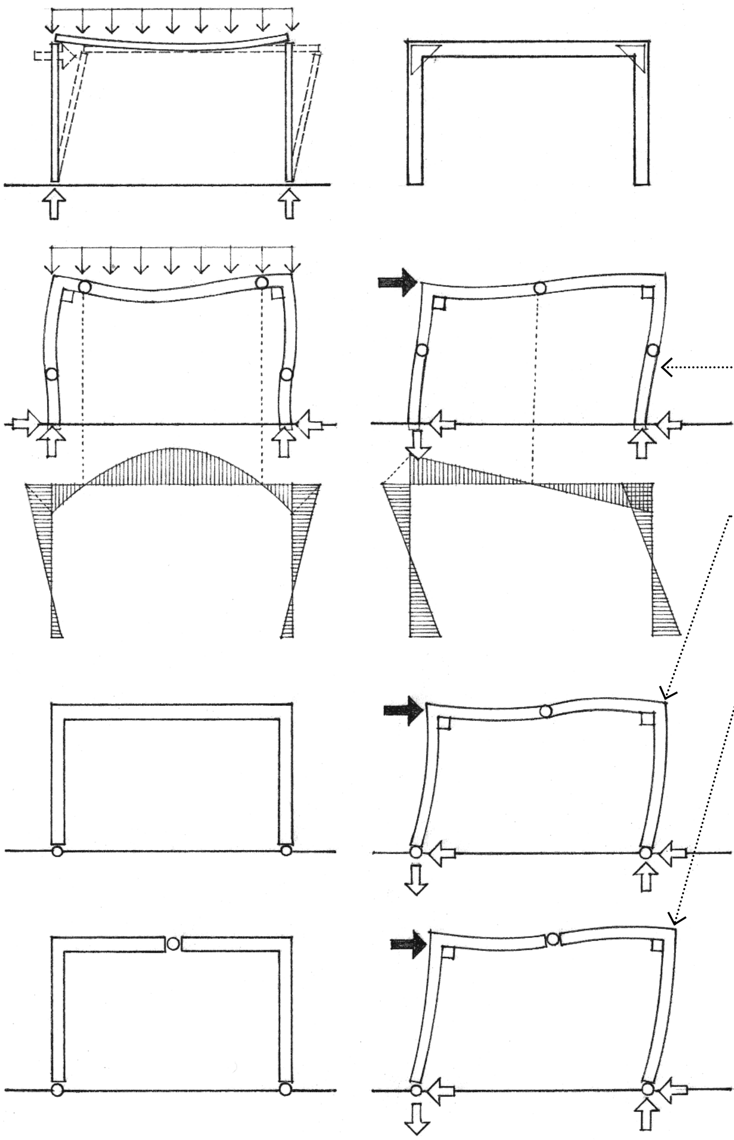


- Panel point is any of the joints between a principal web member and a chord. A truss must be loaded only at its panel points if its members are to be subject only to axial tension or compression. To prevent secondary stresses from developing, the centroidal axes of truss members and the load at a joint should pass through a common point.



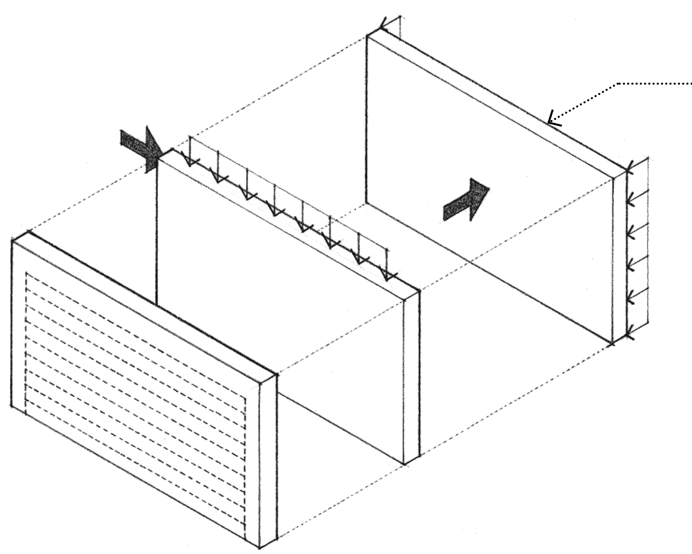
- Zero-force members theoretically carry no direct load; their omission would not alter the stability of the truss configuration.

Frames and Walls



A beam simply supported by two columns is not capable of resisting lateral forces unless it is braced. If the joints connecting the columns and beam are capable of resisting both forces and moments, then the assembly becomes a rigid frame. Applied loads produce axial, bending, and shear forces in all members of the frame because the rigid joints restrain the ends of the members from rotating freely. In addition, vertical loads cause a rigid frame to develop horizontal thrusts at its base. A rigid frame is statically indeterminate and rigid only in its plane.

- Fixed frame is a rigid frame connected to its supports with fixed joints. A fixed frame is more resistant to deflection than a hinged frame but also more sensitive to support settlements and thermal expansion and contraction.
- Hinged frame is a rigid frame connected to its supports with pin joints. The pin joints prevent high bending stresses from developing by allowing the frame to rotate as a unit when strained by support settlements, and to flex slightly when stressed by changes in temperature.
- Three-hinged frame is a structural assembly of two rigid sections connected to each other and to its supports with pin joints. While more sensitive to deflection than either the fixed or hinged frame, the three-hinged frame is least affected by support settlements and thermal stresses. The three-pin joints also permit the frame to be analyzed as a statically determinate structure.



If we fill in the plane defined by two columns and a beam, it becomes a load-bearing wall that acts as a long, thin column in transmitting compressive forces to the ground. Load-bearing walls are most effective when carrying coplanar, uniformly distributed loads and most vulnerable to forces perpendicular to their planes. For lateral stability, load-bearing walls must rely on buttressing with pilasters, cross walls, transverse rigid frames, or horizontal slabs.

Any opening in a loadbearing wall weakens its structural integrity. A lintel or arch must support the load above a door or window opening and allow the compressive stresses to flow around the opening to adjacent sections of the wall.

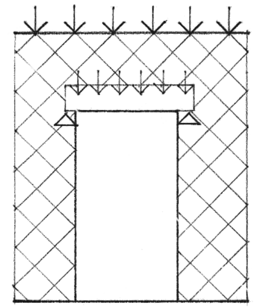
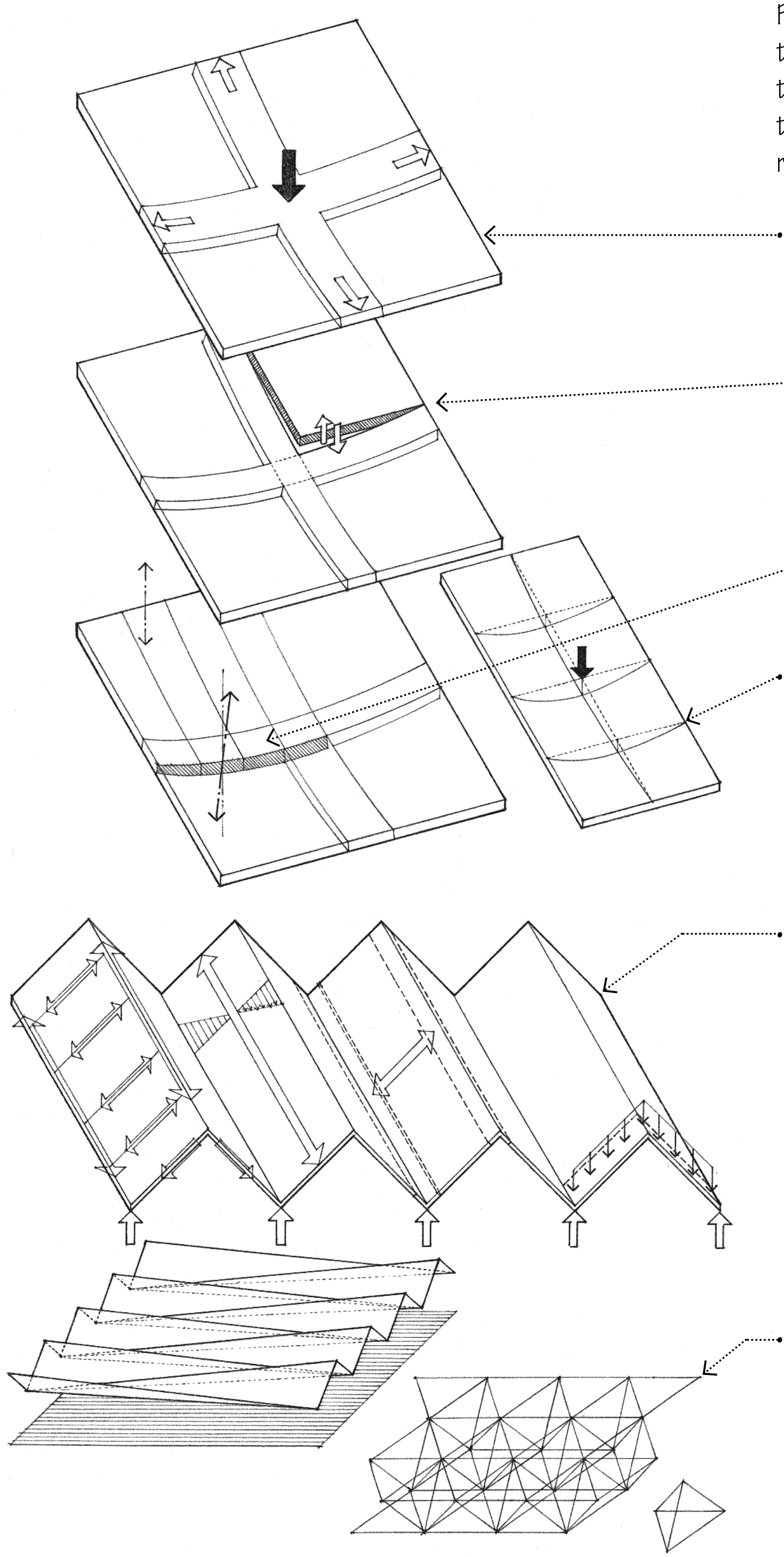


Plate Structures

Plate structures are rigid, planar, usually monolithic structures that disperse applied loads in a multidirectional pattern, with the loads generally following the shortest and stiffest routes to the supports. A common example of a plate structure is a reinforced concrete slab.



- A plate can be envisioned as a series of adjacent beam strips interconnected continuously along their lengths. As an applied load is transmitted to the supports through bending of one beam strip, the load is distributed over the entire plate by vertical shear transmitted from the deflected strip to adjacent strips. The bending of one beam strip also causes twisting of transverse strips, whose torsional resistance increases the overall stiffness of the plate. Therefore, while bending and shear transfer an applied load in the direction of the loaded beam strip, shear and twisting transfer the load at right angles to the loaded strip.

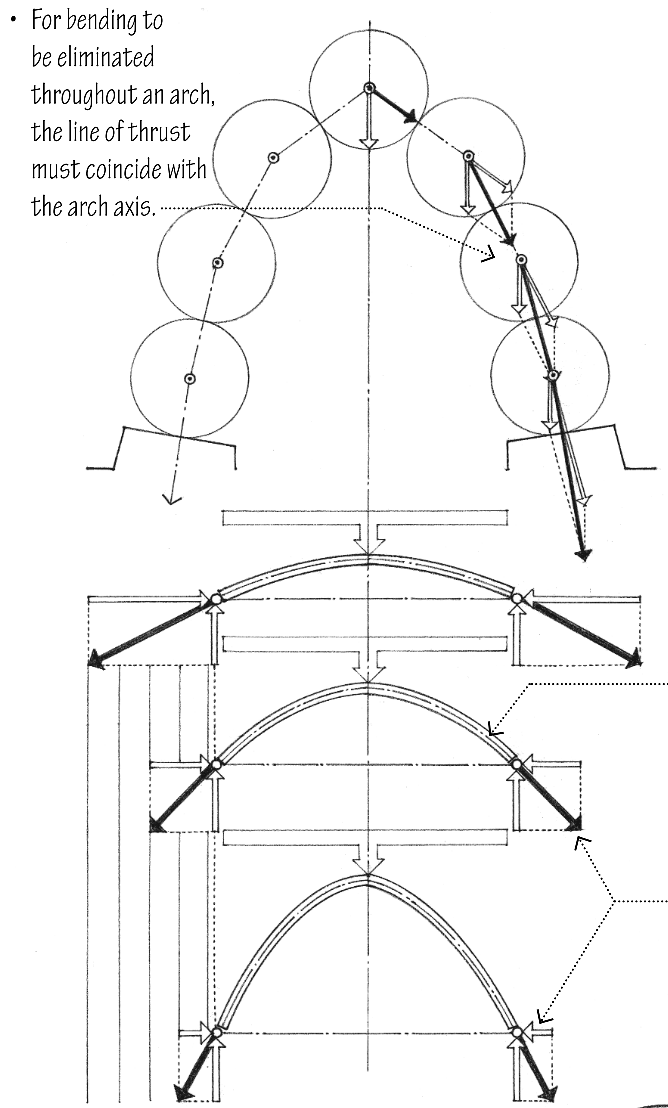
- A plate should be square or nearly square to ensure that it behaves as a two-way structure. As a plate becomes more rectangular than square, the two-way action decreases and a one-way system spanning the shorter direction develops because the shorter plate strips are stiffer and carry a greater portion of the load.

- Folded plate structures are composed of thin, deep elements joined rigidly along their boundaries and forming sharp angles to brace each other against lateral buckling. Each plane behaves as a beam in the longitudinal direction. In the short direction, the span is reduced by each fold acting as a rigid support. Transverse strips behave as a continuous beam supported at fold points. Vertical diaphragms or rigid frames stiffen a folded plate against deformation of the fold profile. The resulting stiffness of the cross section enables a folded plate to span relatively long distances.

- A space frame is composed of short rigid linear elements triangulated in three dimensions and subject only to axial tension or compression. The simplest spatial unit of a space frame is a tetrahedron that has four joints and six structural members. Because the structural behavior of a space frame is analogous to that of a plate structure, its supporting bay should be square or nearly square to ensure that it acts as a two-way structure. Enlarging the bearing area of the supports increases the number of members into which shear is transferred and reduces the forces in the members.

Arches and Vaults

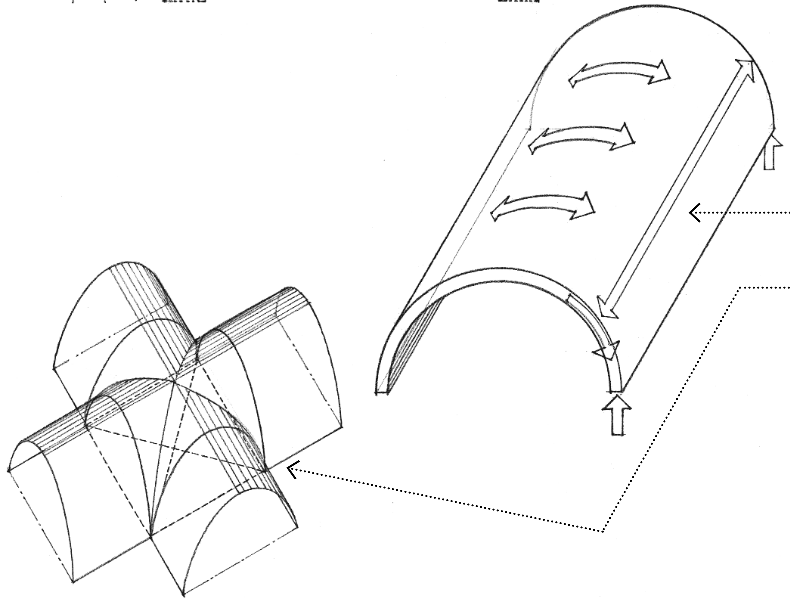
Columns, beams, slabs, and bearing walls are the most common structural elements because of the rectilinear building geometry they are capable of generating. There are, however, other means of spanning and enclosing space. These are generally form-active elements that, through their shape and geometry, make efficient use of their material for the distances spanned. While beyond the scope of this book, they are briefly described in the following section.



Arches are curved structures for spanning an opening, designed to support a vertical load primarily by axial compression. They transform the vertical forces of a supported load into inclined components and transmit them to abutments on either side of the archway.

- Masonry arches are constructed of individual wedge-shaped stone or brick voussoirs; for more information on masonry arches.
- Rigid arches consist of curved, rigid structures of timber, steel, or reinforced concrete capable of carrying some bending stresses.

- The thrust of an arched structure on its abutments is proportional to the total load and span, and inversely proportional to the rise.



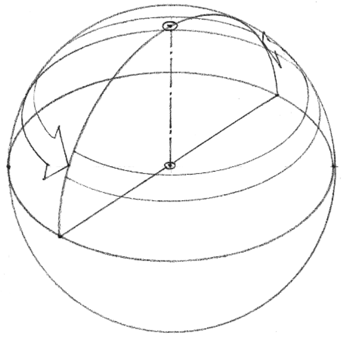
Vaults are arched structures of stone, brick, or reinforced concrete, forming a ceiling or roof over a hall, room, or other wholly or partially enclosed space. Because a vault behaves as an arch extended in a third dimension, the longitudinal supporting walls must be buttressed to counteract the outward thrusts of the arching action.

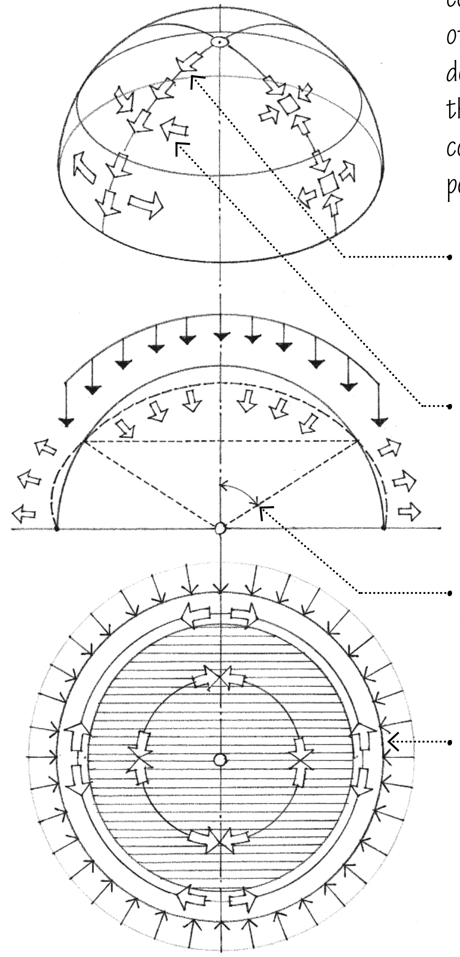
- Barrel vaults have semicircular cross sections.

- Groin or cross vaults are compound vaults formed by the perpendicular intersection of two vaults, forming arched diagonal arises called groins.

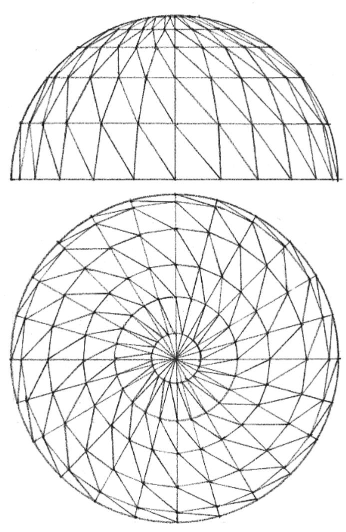
Domes

A dome is a spherical surface structure having a circular plan and constructed of stacked blocks, a continuous rigid material like reinforced concrete, or of short, linear elements, as in the case of a geodesic dome. A dome is similar to a rotated arch except that circumferential forces are developed that are compressive near the crown and tensile in the lower portion.

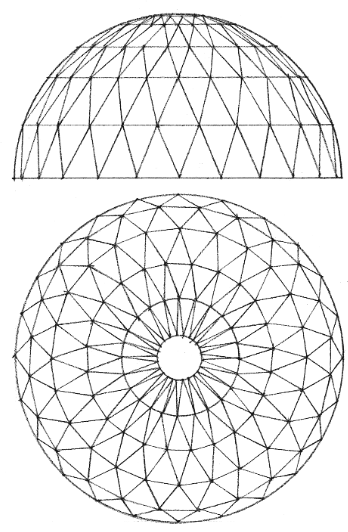




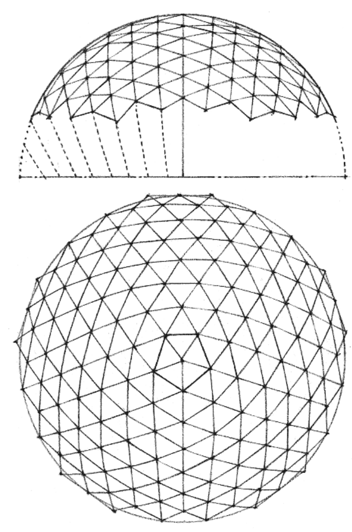
- Meridional forces acting along a vertical section cut through the surface of the dome are always compressive under full vertical loading.
- Hoop forces, restraining the out-of-plane movement of the meridional strips in the shell of a dome, are compressive in the upper zone and tensile in the lower zone.
- The transition from compressive hoop forces to tensile hoop forces occurs at an angle of from 45° to 60° from the vertical axis.
- A tension ring encircles the base of a dome to contain the outward components of the meridional forces. In a concrete dome, this ring is thickened and reinforced to handle the bending stresses caused by the differing elastic deformations of the ring and shell.



Schwedler dome



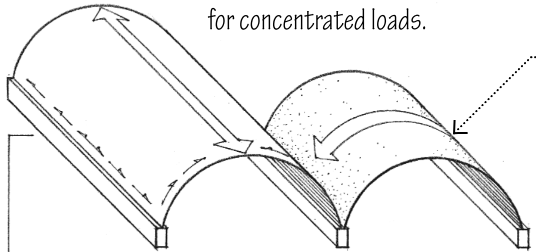
Lattice dome



Geodesic dome

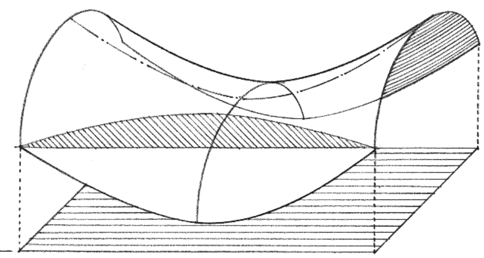
Shell Structures

Shells are thin, curved plate structures typically constructed of reinforced concrete. They are shaped to transmit applied forces by membrane stresses—the compressive, tensile, and shear stresses acting in the plane of their surfaces. A shell can sustain relatively large forces if uniformly applied. Because of its thinness, however, a shell has little bending resistance and is unsuitable for concentrated loads.

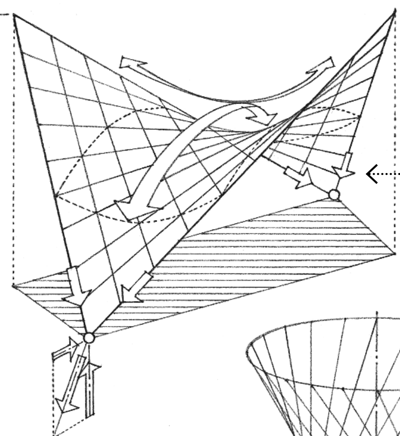


- Barrel shells are cylindrical shell structures. If the length of a barrel shell is three or more times its transverse span, it behaves as a deep beam with a curved section spanning in the longitudinal direction. If it is relatively short, it exhibits archlike action. Tie rods or transverse rigid frames are required to counteract the outward thrusts of the arching action.

- Translational surfaces are generated by sliding a plane curve along a straight line or over another plane curve.



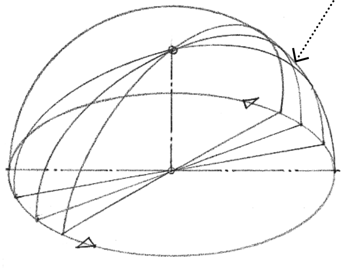
- A hyperbolic paraboloid is a surface generated by sliding a parabola with downward curvature along a parabola with upward curvature, or by sliding a straight line segment with its ends on two skew lines. It can be considered to be both a translational and a ruled surface.

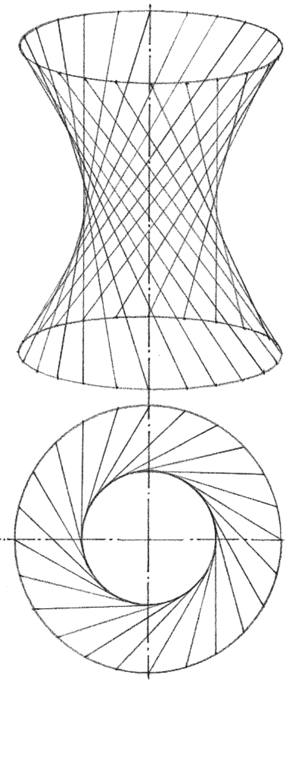


- Saddle surfaces have an upward curvature in one direction and a downward curvature in the perpendicular direction. In a saddle-surfaced shell structure, regions of downward curvature exhibit archlike action, while regions of upward curvature behave as a cable structure. If the edges of the surface are not supported, beam behavior may also be present.

- Ruled surfaces are generated by the motion of a straight line. Because of its straight-line geometry, a ruled surface is generally easier to form and construct than a rotational or translational surface.

- Rotational surfaces are generated by rotating a plane curve about an axis. Spherical, elliptical, and parabolic dome surfaces are examples of rotational surfaces.

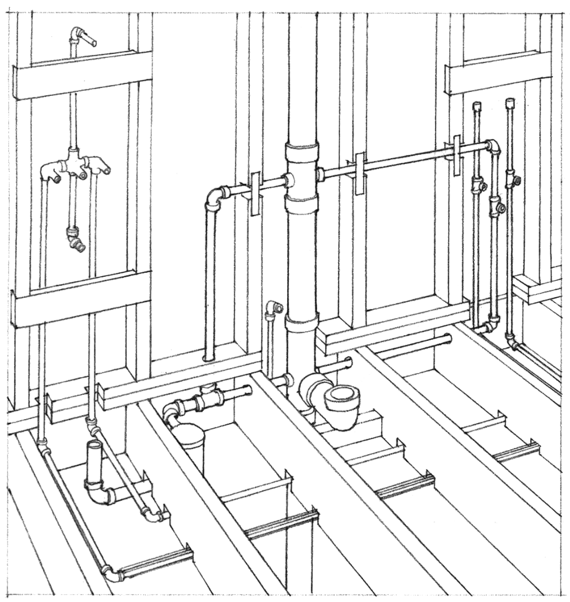




- A one-sheet hyperboloid is a ruled surface generated by sliding an inclined line segment on two horizontal circles. Its vertical sections are hyperbolas.

12 Building Systems

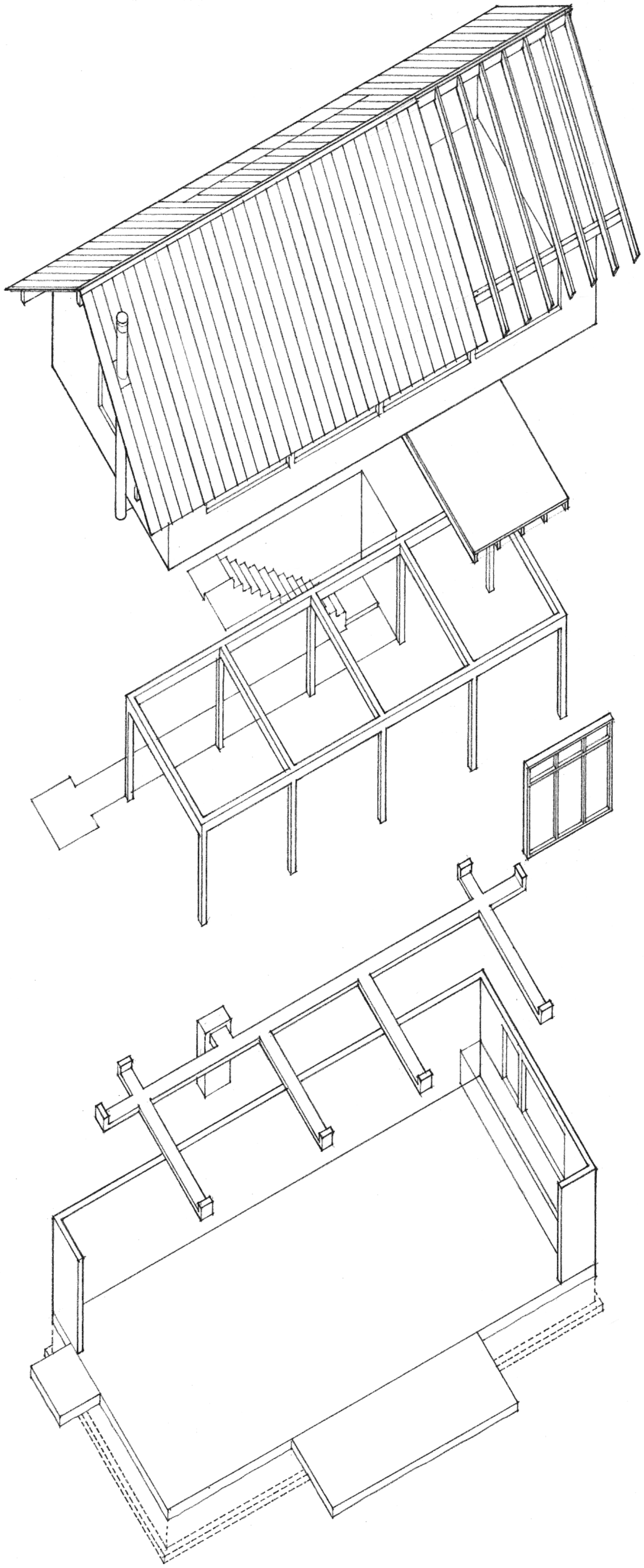
How Do Buildings Work?



Architecture is a complex synthesis of interrelated systems. These systems range from the compositional organization of space and form to the enclosure that keeps the interior dry to the mechanical systems that regulate temperature and humidity of the interior environment. These various systems all collaborate to make a single functional piece of architecture.

The architect is not responsible for all of the disparate systems involved in the function of a building, but those systems must all be considered and accounted for in the design process. Architectural design requires a synthetic thinking that considers ways these systems are interrelated. This helps the architect construct strategies for design that optimize efficient operation of these various systems toward the ultimate design goals of the project.

In this chapter, the many systems that contribute to operation of a building will be discussed. They will be considered for their influence over the design process and for their relationships to other systems of a building.



Building Systems Outlined

Structural System

The structural system of a building is designed and constructed to support and transmit applied gravity and lateral loads safely to the ground without exceeding the allowable stresses in its members.

- The superstructure is the vertical extension of a building above the foundation.
- Columns, beams, and load-bearing walls support floor and roof structures.
- The substructure is the underlying structure forming the foundation of a building.

Enclosure System

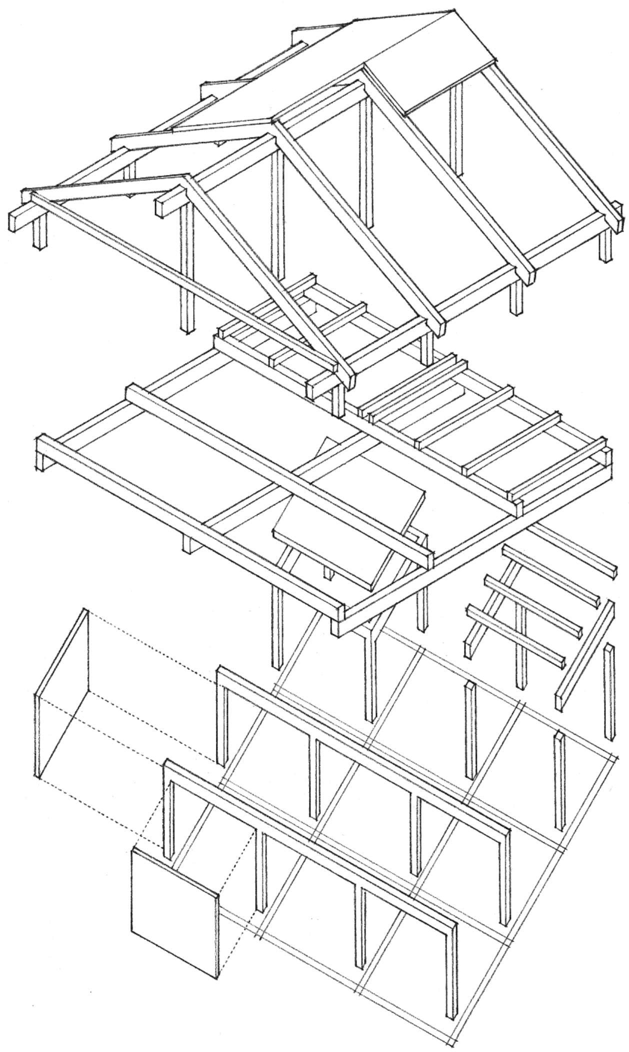
The enclosure system is the shell or envelope of a building, consisting of the roof, exterior walls, windows, and doors.

- The roof and exterior walls shelter interior spaces from inclement weather and control moisture, heat, and air flow through the layering of construction assemblies.
- Exterior walls and roofs also dampen noise and provide security and privacy for the occupants of a building.
- Doors provide physical access.
- Windows provide access to light, air, and views.
- Interior walls and partitions subdivide the interior of a building into spatial units.

Mechanical Systems

The mechanical systems of a building provide essential services to a building.

- The water supply system provides potable water for human consumption and sanitation.
- The sewage disposal system removes fluid waste and organic matter from a building.
- Heating, ventilating, and air-conditioning systems condition the interior spaces of a building for the environmental comfort of the occupants.
- The electrical system controls, meters, and protects the electric power supply to a building, and distributes it in a safe manner for power, lighting, security, and communication systems.
- Vertical transportation systems carry people and goods from one level to another in medium- and high-rise buildings.
- Fire-fighting systems detect and extinguish fires.
- Structures may also require waste disposal and recycling systems.



The manner in which we select, assemble, and integrate the various building systems in construction should take into account the following factors:

Performance Requirements
- Structural compatibility, integration, and safety
- Fire resistance, prevention, and safety
- Allowable or desirable thickness of construction assemblies
- Control of heat and air flow through building assemblies
- Control of migration and condensation of water vapor
- Accommodation of building movement because of settlement, structural deflection, and expansion or contraction with changes in temperature and humidity
- Noise reduction, sound isolation, and acoustical privacy
- Resistance to wear, corrosion, and weathering
- Finish, cleanliness, and maintenance requirements
- Safety in use

Aesthetic Qualities
- Desired relationship of building to its site, adjacent properties, and neighborhood
- Preferred qualities of form, massing, color, pattern, texture, and detail

Regulatory Constraints
- Compliance with zoning ordinances and building codes

Economic Considerations
- Initial cost comprising material, transportation, equipment, and labor costs
- Life-cycle costs, which include not only initial cost, but also maintenance and operating costs, energy consumption, useful lifetime, demolition and replacement costs, and interest on invested money

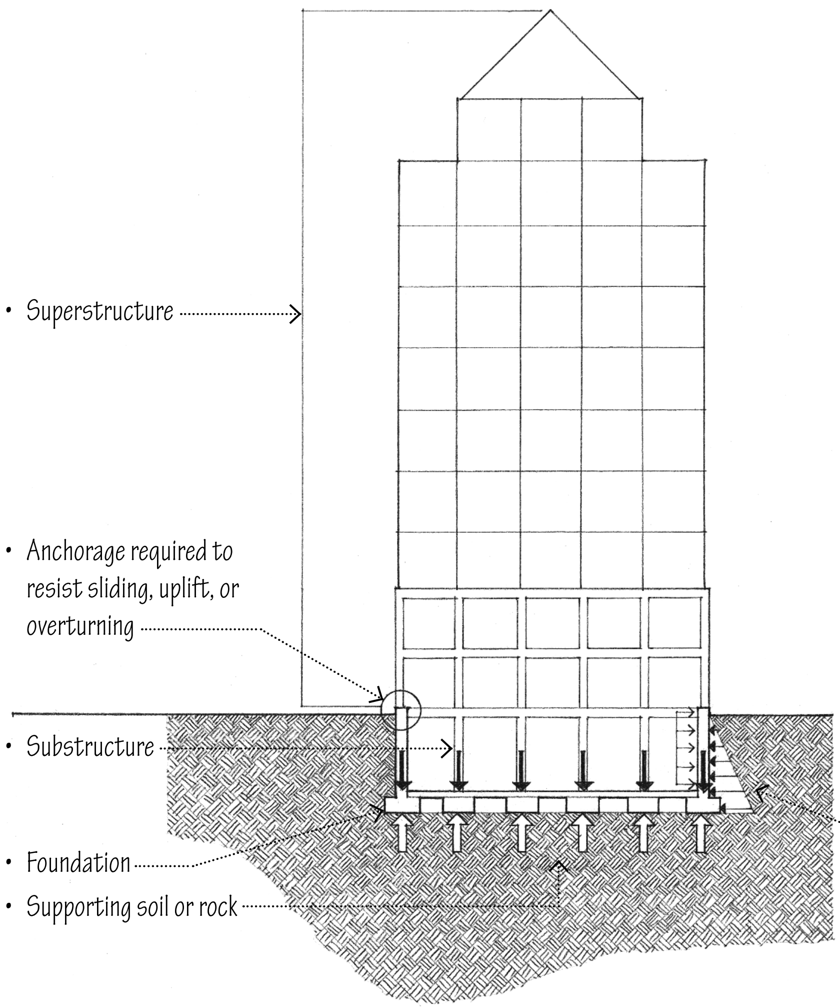
Environmental Impact
- Conservation of energy and resources through siting and building design
- Energy efficiency of mechanical systems
- Use of resource-efficient and nontoxic materials

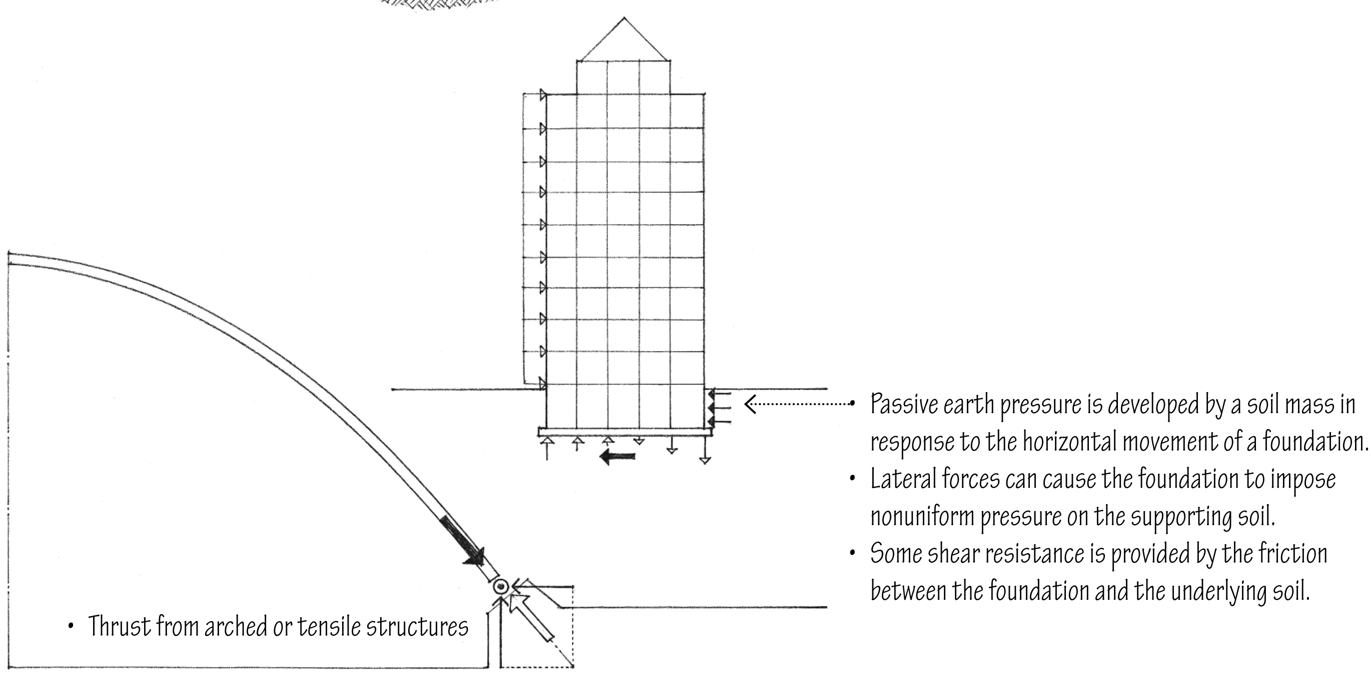
Construction Practices
- Safety requirements
- Allowable tolerances and appropriate fit
- Conformance to industry standards and assurance
- Division of work between the shop and the field
- Division of labor and coordination of building trades
- Budget constraints
- Construction equipment required
- Erection time required
- Provisions for inclement weather

Foundation Systems

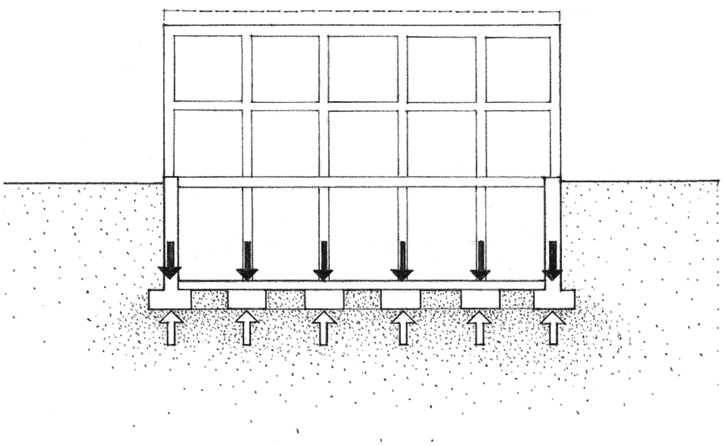
The foundation is the lowest division of a building—its substructure—constructed partly or wholly below the surface of the ground. Its primary function is to support and anchor the superstructure above and transmit its loads safely into the earth. Because it serves as a critical link in the distribution and resolution of building loads, the foundation system must be designed to both accommodate the form and layout of the superstructure above and respond to the varying conditions of soil, rock, and water below.

The principal loads on a foundation are the combination of dead and live loads acting vertically on the superstructure. In addition, a foundation system must anchor the superstructure against wind-induced sliding, overturning, and uplift, withstand the sudden ground movements of an earthquake, and resist the pressure imposed by the surrounding soil mass and groundwater on basement walls. In some cases, a foundation system may also have to counter the thrust from arched or tensile structures.

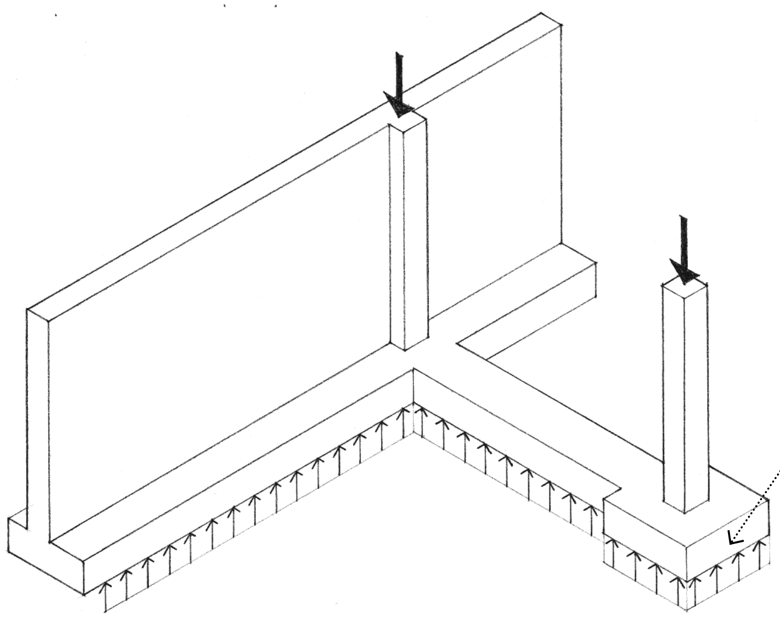


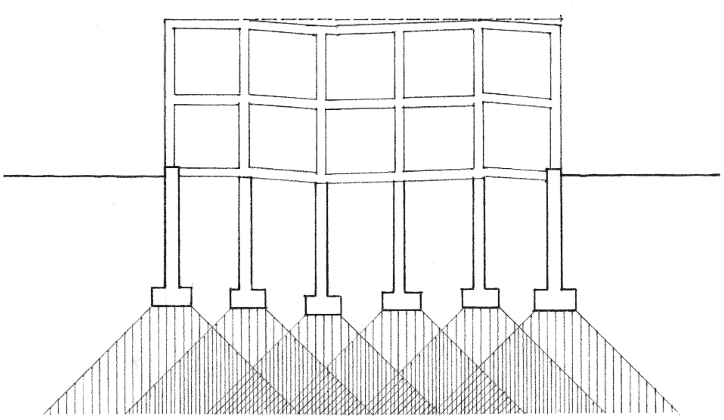


Settlement is the gradual subsiding of a structure as the soil beneath its foundation consolidates under loading. As a building is constructed, some settlement is to be expected as the load on the foundation increases and causes a reduction in the volume of soil voids containing air or water. This consolidation is usually slight and occurs rather quickly as loads are applied on dense, granular soils, such as coarse sand and gravel. When the foundation soil is a moist, cohesive clay, which has a scale-like structure and a relatively large percentage of voids, consolidation can be quite large and occur slowly over a longer period of time.

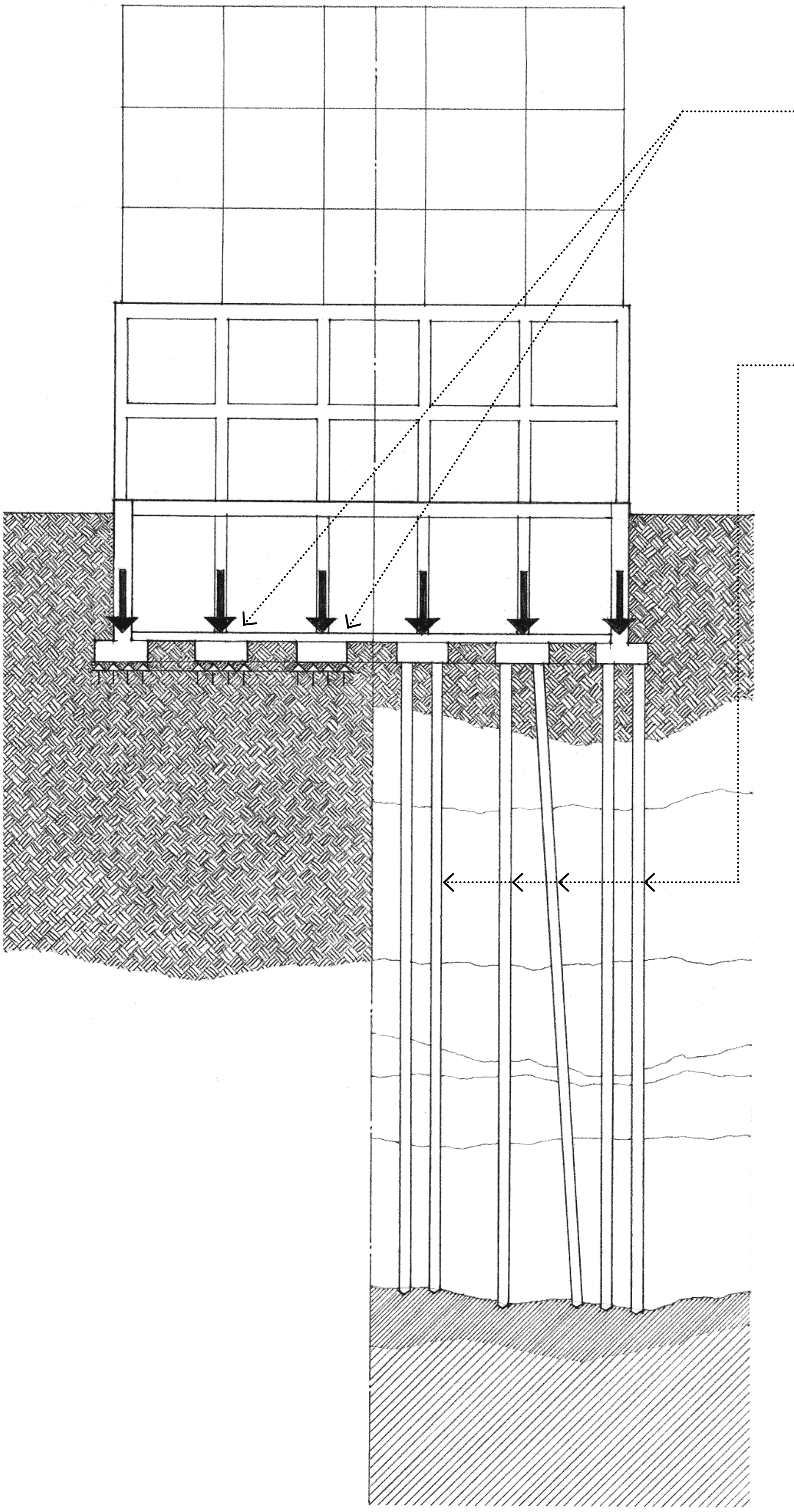


A properly designed and constructed foundation system should distribute its loads so that whatever settlement occurs is minimal or is uniformly distributed under all portions of the structure. This is accomplished by laying out and proportioning the foundation supports so that they transmit an equal load per unit area to the supporting soil or rock without exceeding its bearing capacity.





Differential settlement—the relative movement of different parts of a structure caused by uneven consolidation of the foundation soil—can cause a building to shift out of plumb and cracks to occur in its foundation, structure, or finishes. If extreme, differential settlement can result in the failure of the structural integrity of a building.



We can classify foundation systems into two broad categories—shallow foundations and deep foundations.

Shallow Foundations
Shallow or spread foundations are employed when stable soil of adequate bearing capacity occurs relatively near to the ground surface. They are placed directly below the lowest part of a substructure and transfer building loads directly to the supporting soil by vertical pressure.

Deep Foundations
Deep foundations are employed when the soil underlying a foundation is unstable or of inadequate bearing capacity. They extend down through unsuitable soil to transfer building loads to a more appropriate bearing stratum of rock or dense sands and gravels well below the superstructure.

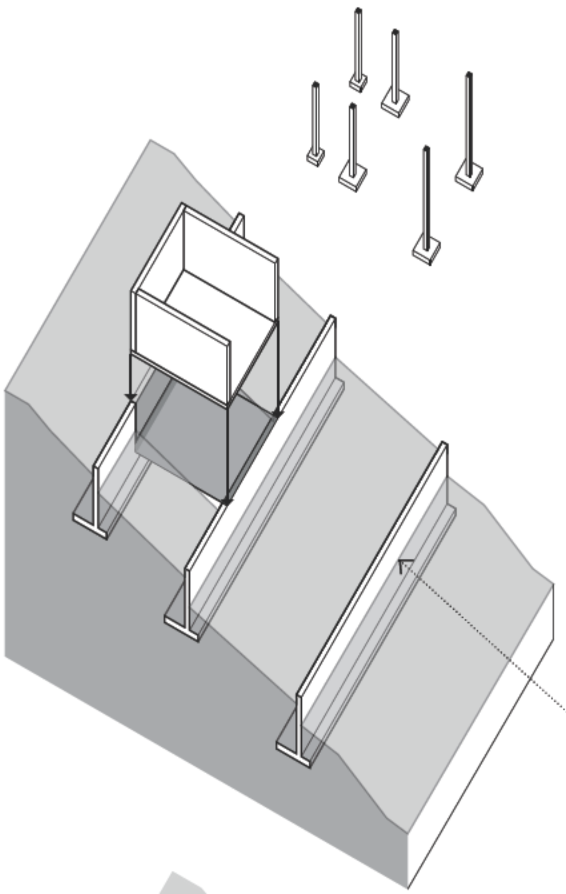
Factors to consider in selecting and designing the type of foundation system for a building include:

- Pattern and magnitude of building loads
- Subsurface and groundwater conditions
- Topography of the site
- Impact on adjacent properties
- Building code requirements
- Construction method and risk

The design of a foundation system requires professional analysis and design by a qualified structural engineer. When designing anything other than a single-family dwelling on stable soil, it is also advisable to have a geotechnical engineer undertake a subsurface investigation in order to determine the type and size of foundation system required for the building design.

Building on Slopes

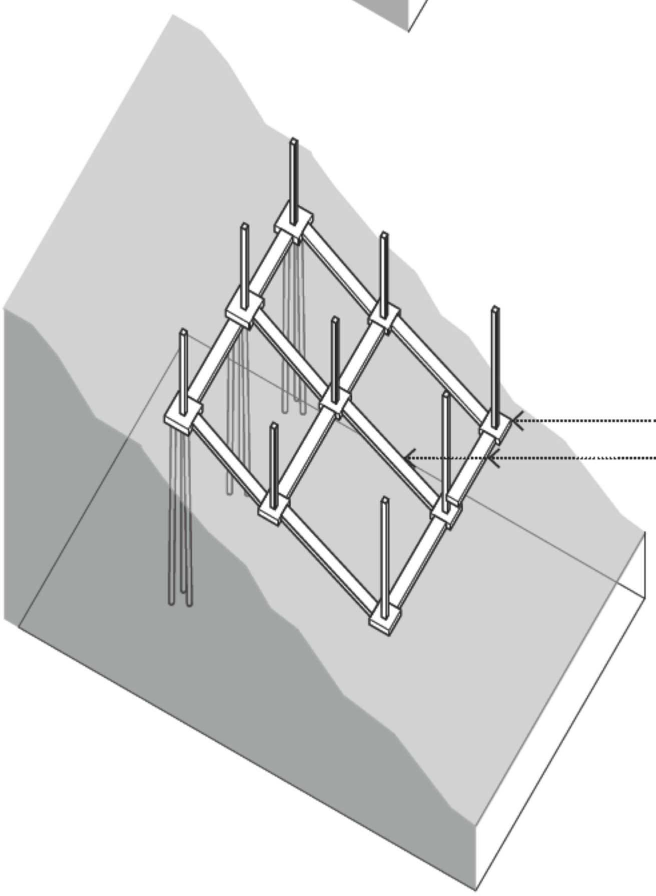
Pile foundations can be used on irregular or sloping topography, particularly where the surface soil on the slope may be unstable and the pilings can extend down to bear on or in more stable stratum of soil or rock. In such cases, it may not be necessary to retain soil, and the location of the piles can align with the desired column locations in the building.



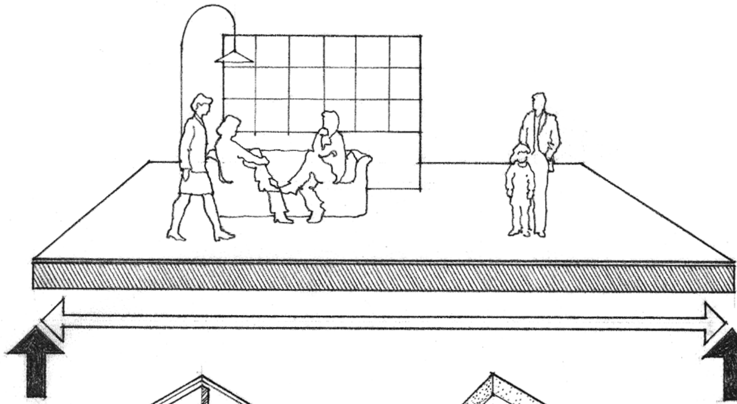
When it is desirable or necessary to excavate into a slope, retaining walls are often employed to contain the mass of earth above the grade change. The retained soil is considered to act as a fluid that exerts lateral pressure on the face of the retaining wall, tending to cause the wall to slide laterally or to overturn. The overturning moment created by the lateral soil pressure and the opposing resistance of the wall's foundation is critically dependent on the height of the wall. The moment increases with the square of the height of the earth that is retained. As a retaining wall becomes taller, it may be necessary to install tiebacks to piling or to build in counterforts—cross walls that stiffen the wall slab and add weight to its footing.

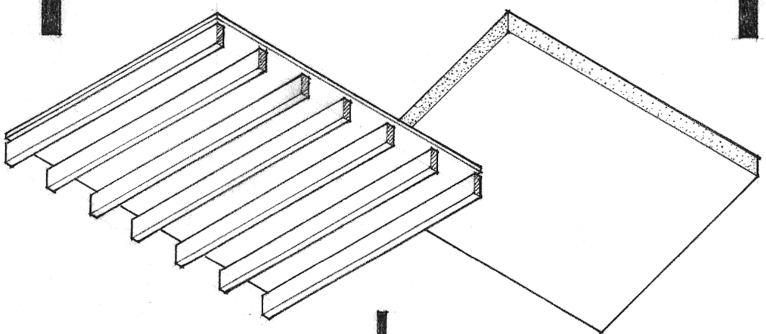
A series of retaining walls parallel to the slope can provide continuous support for bearing walls in the superstructure of the building. It is not advisable to add the weight of the building to the soil behind the retaining wall. The location of the retaining walls should therefore coincide with lines of support in the building above.

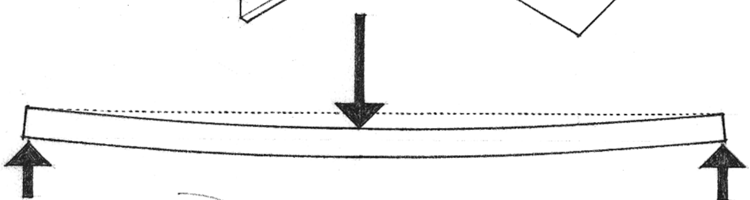
For small projects, particularly when the design does not require excavation into a sloping site, grade beams may be used to tie the foundation into a single, rigid unit that is in turn anchored to piling, usually at the upper portion of the site. This has been successful where minimum disruption of the site is desirable and on sites that are primarily accessible from the high side.

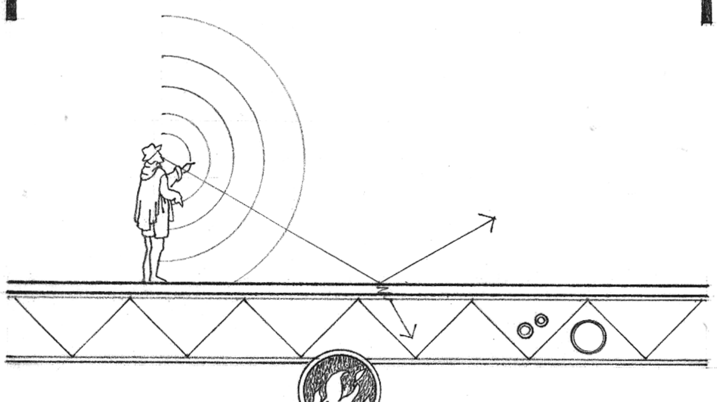


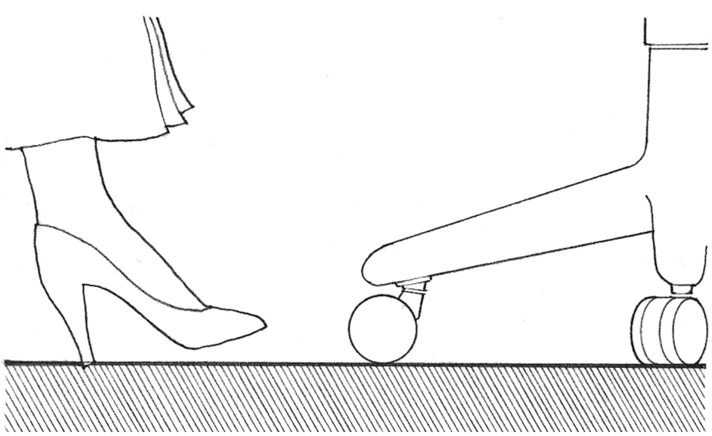
Floor Systems











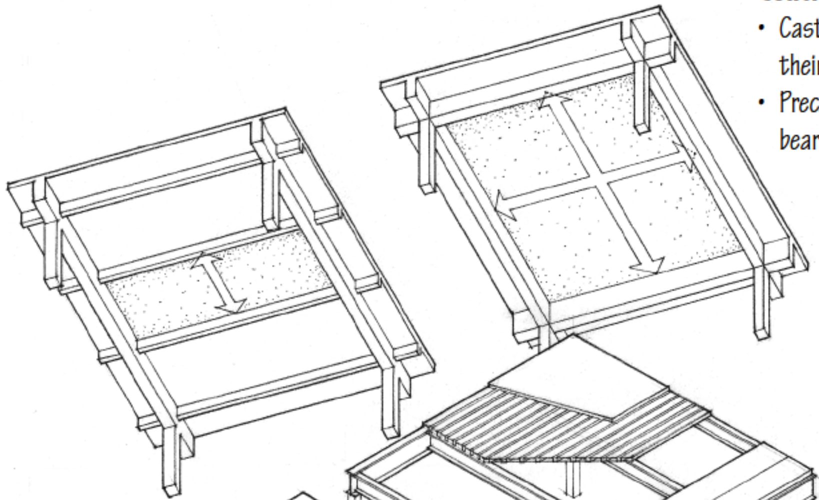
Floor systems are the horizontal planes that must support both live loads—people, furnishings, and movable equipment—and dead loads—the weight of the floor construction itself. Floor systems must transfer their loads horizontally across space to either beams and columns or to load-bearing walls. Rigid floor planes can also be designed to serve as horizontal diaphragms that act as thin, wide beams in transferring lateral forces to shear walls.

A floor system may be composed of a series of linear beams and joists overlaid with a plane of sheathing or decking, or consist of a nearly homogeneous slab of reinforced concrete. The depth of a floor system is directly related to the size and proportion of the structural bays it must span and the strength of the materials used. The size and placement of any cantilevers and openings within the floor plane should also be considered in the layout of the structural supports for the floor. The edge conditions of the floor structure and its connection to supporting foundation and wall systems affect both the structural integrity of a building and its physical appearance.

Because it must safely support moving loads, a floor system should be relatively stiff while maintaining its elasticity. Because of the detrimental effects that excessive deflection and vibration would have on finish flooring and ceiling materials, as well as concern for human comfort, deflection rather than bending becomes the critical controlling factor.

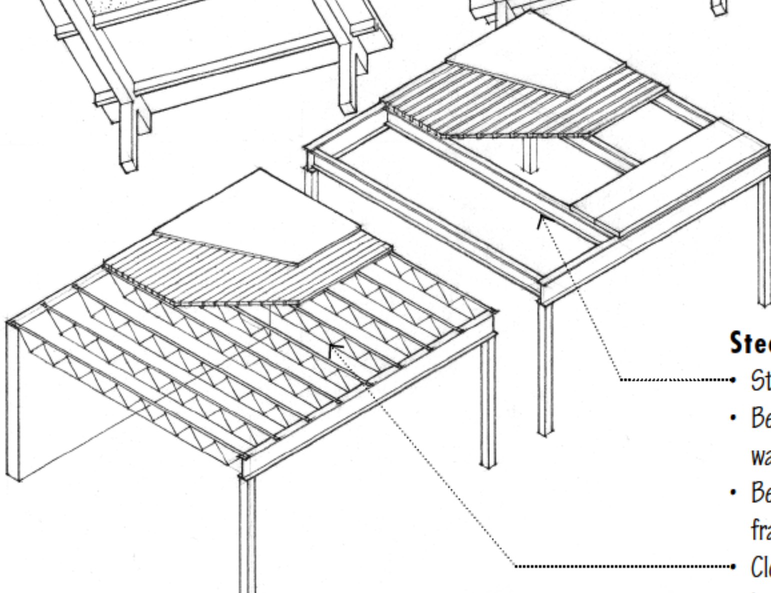
The depth of the floor construction and the cavities within it should be considered if it is necessary to accommodate runs of mechanical or electrical lines within the floor system. For floor systems between habitable spaces stacked one above another, additional factors to consider are the blockage of both airborne and structure-borne sound and the fire-resistance rating of the assembly.

Except for exterior decks, floor systems are not normally exposed to weather. Because they all must support traffic, however, durability, resistance to wear, and maintenance requirements are factors to consider in the selection of a floor finish and the system required to support it.



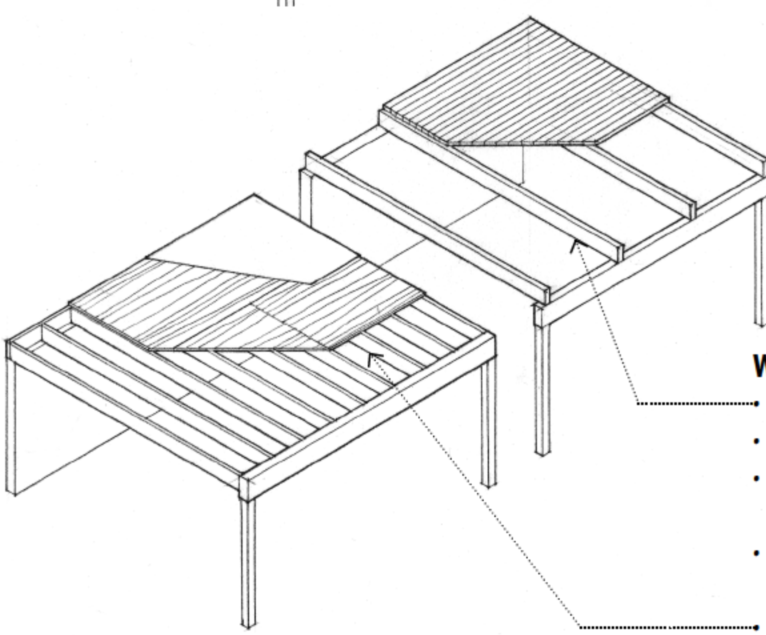
Concrete

- Cast-in-place concrete floor slabs are classified according to their span and cast form.
- Precast concrete planks may be supported by beams or load-bearing walls.



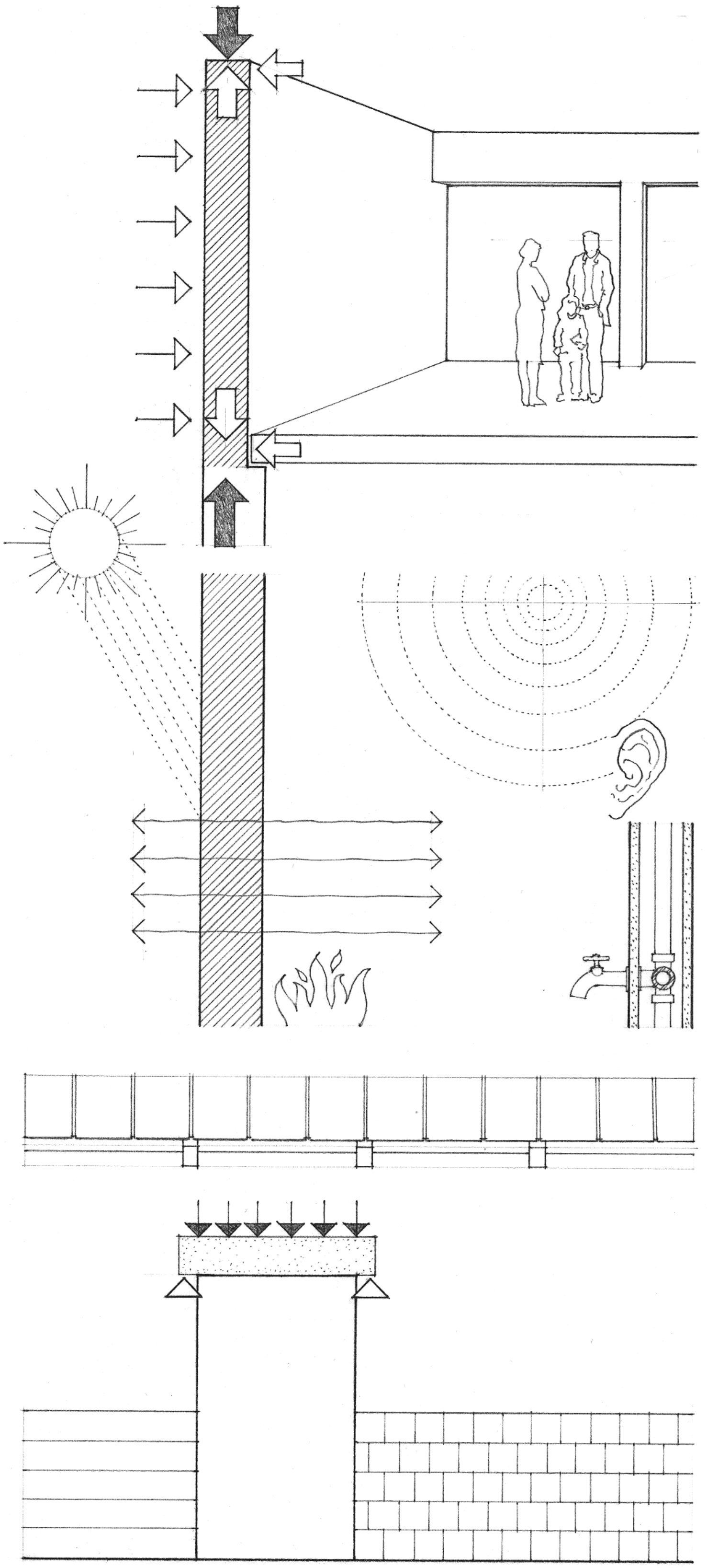
Steel

- Steel beams support steel decking or precast concrete planks.
- Beams may be supported by girders, columns, or load-bearing walls.
- Beam framing is typically an integral part of a steel skeleton frame system.
- Closely spaced light-gauge or open-web joists may be supported by beams or load-bearing walls.
- Steel decking or wood planks have relatively short spans.
- Joists have limited overhang potential.



Wood

- Wood beams support structural planking or decking.
- Beams may be supported by girders, posts, or load-bearing walls.
- Concentrated loads and floor openings may require additional framing.
- Underside of floor structure may be left exposed; an applied ceiling is optional.
- Relatively small, closely spaced joists may be supported by beams or load-bearing walls.
- Subflooring, underlayment, and applied ceiling finishes have relatively short spans.
- Joist framing is flexible in shape and form.



Wall Systems

Walls are the vertical constructions of a building that enclose, separate, and protect its interior spaces.

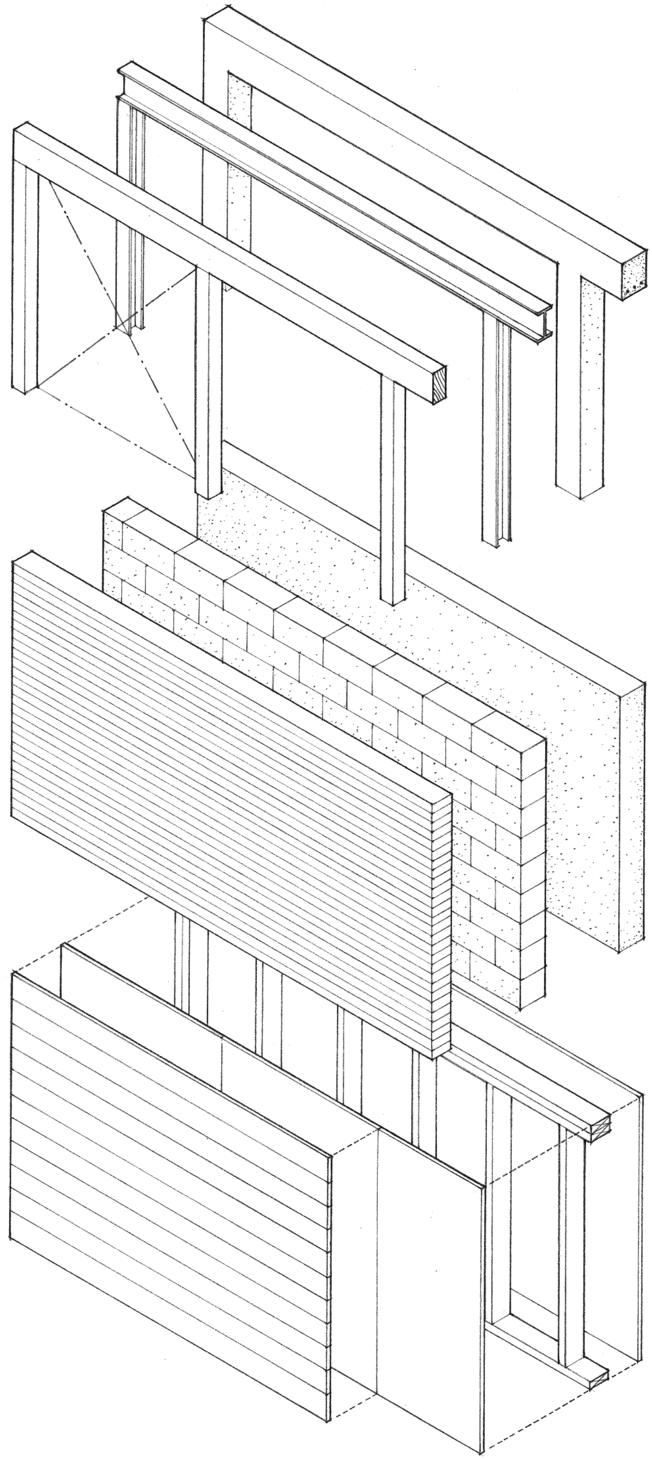
They may be load-bearing structures of homogeneous or composite construction designed to support imposed loads from floors and roofs, or consist of a framework of columns and beams with nonstructural panels attached to or filling in between them. The pattern of these load-bearing walls and columns should be coordinated with the layout of the interior spaces of a building.

In addition to supporting vertical loads, exterior wall constructions must be able to withstand horizontal wind loading. If rigid enough, they can serve as shear walls and transfer lateral wind and seismic forces to the ground foundation.

Because exterior walls serve as a protective shield against the weather for the interior spaces of a building, their construction should control the passage of heat, infiltrating air, sound, moisture, and water vapor. The exterior skin, which may be either applied to or integral with the wall structure, should be durable and resistant to the weathering effects of sun, wind, and rain. Building codes specify the fire-resistance rating of exterior walls, load-bearing walls, and interior partitions.

The interior walls or partitions, which subdivide the space within a building, may be either structural or non-load-bearing. Their construction should be able to support the desired finish materials, provide the required degree of acoustical separation, and accommodate when necessary the distribution and outlets of mechanical and electrical services.

Openings for doors and windows must be constructed so that any vertical loads from above are distributed around the openings and not transferred to the door and window units themselves. Their size and location are determined by the requirements for natural light, ventilation, view, and physical access, as well as the constraints of the structural system and modular wall materials.



Structural Frames

- Concrete frames are typically rigid frames and qualify as noncombustible, fire-resistive construction.
- Noncombustible steel frames may utilize moment connections and require fireproofing to qualify as fire-resistive construction.
- Timber frames require diagonal bracing or shear planes for lateral stability and may qualify as heavy timber construction if used with noncombustible, fire-resistive exterior walls and if the members meet the minimum size requirements specified in the building code.
- Steel and concrete frames are able to span greater distances and carry heavier loads than timber structures.
- Structural frames can support and accept a variety of nonbearing or curtain wall systems.
- The detailing of connections is critical for structural and visual reasons when the frame is left exposed.

Concrete and Masonry Bearing Walls

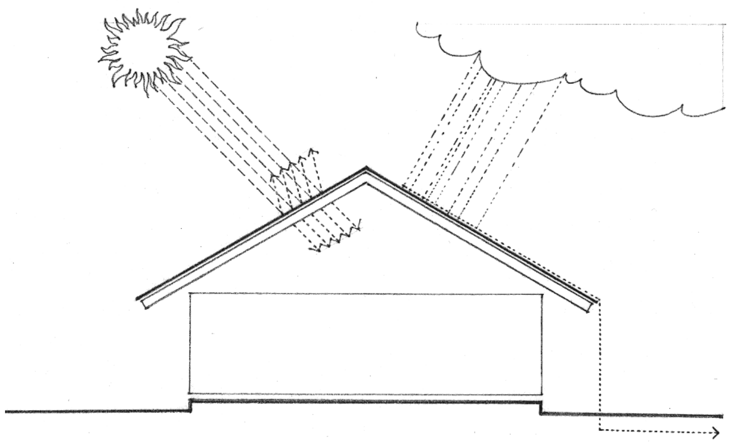
- Concrete and masonry walls qualify as noncombustible construction and rely on their mass for their load-carrying capability.
- While strong in compression, concrete and masonry require reinforcing to handle tensile stresses.
- Height-to-width ratio, provisions for lateral stability, and proper placement of expansion joints are critical factors in wall design and construction.
- Wall surfaces may be left exposed.

Metal and Wood Stud Walls

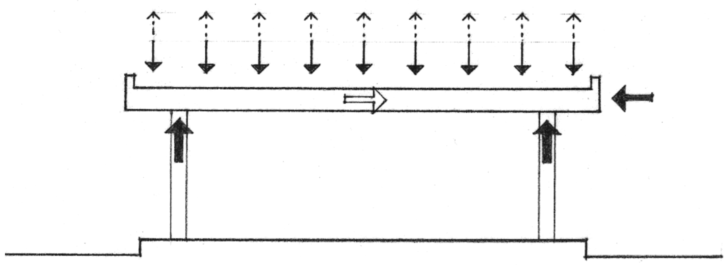
- Studs of cold-formed metal or wood are normally spaced every 16 in. or 24 in (406 or 610); this spacing is related to the width and length of common sheathing materials.
- Studs carry vertical loads while sheathing or diagonal bracing stiffens the plane of the wall.
- Cavities in the wall frame can accommodate thermal insulation, vapor retarders, and mechanical distribution and outlets of mechanical and electrical services.
- Stud framing can accept a variety of interior and exterior wall finishes; some finishes require a nail-base sheathing.
- The finish materials determine the fire-resistance rating of the wall assembly.
- Stud wall frames may be assembled on site or panelized off site.
- Stud walls are flexible in form because of the workability of relatively small pieces and the various means of fastening available.

Roof Systems

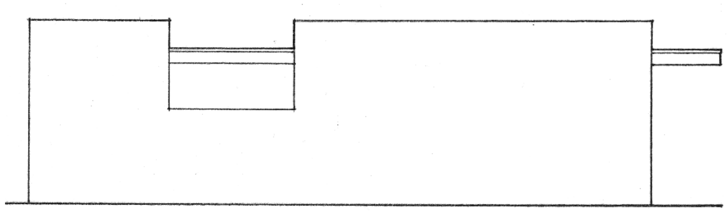
The roof system functions as the primary sheltering element for the interior spaces of a building. The form and slope of a roof must be compatible with the type of roofing—shingles, tiles, or a continuous membrane—used to shed rainwater and melting snow to a system of drains, gutters, and downspouts. The construction of a roof should also control the passage of moisture vapor, the infiltration of air, and the flow of heat and solar radiation. And depending on the type of construction required by the building code, the roof structure and assembly may have to resist the spread of fire.



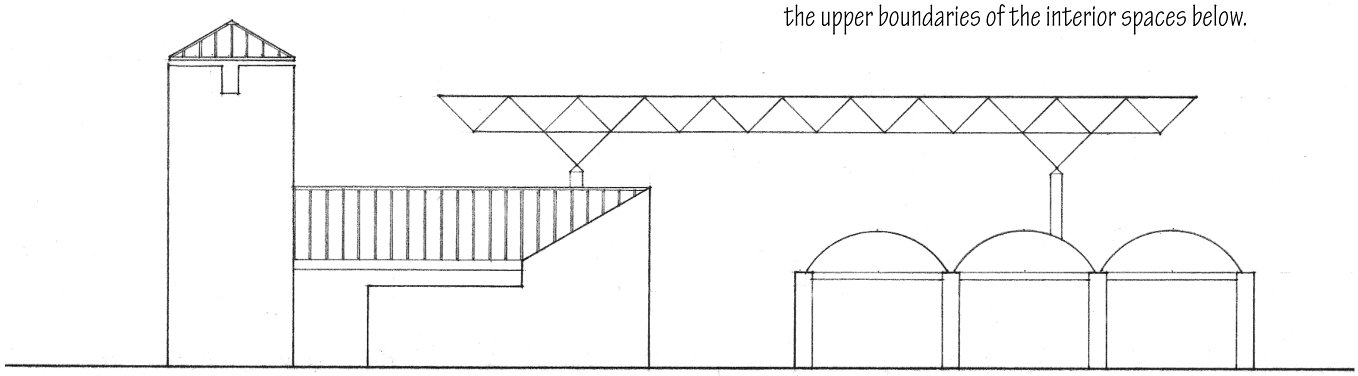
Like floor systems, a roof must be structured to span across space and carry its own weight as well as the weight of any attached equipment and accumulated rain and snow. Flat roofs used as decks are also subject to live occupancy loads. In addition to these gravity loads, the planes of the roof may be required to resist lateral wind and seismic forces, as well as uplifting wind forces, and transfer these forces to the supporting structure.

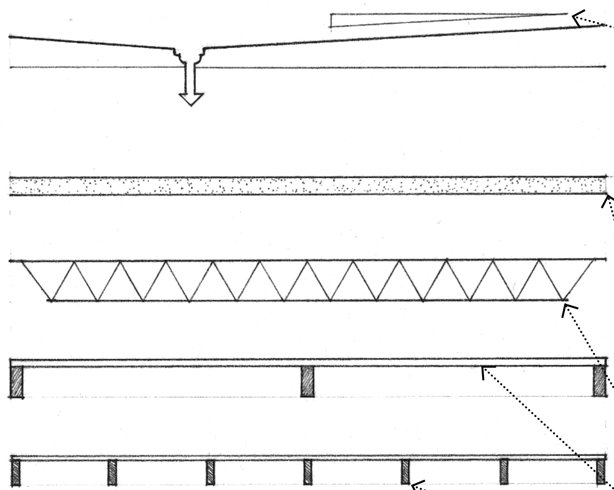


Because the gravity loads for a building originate with the roof system, its structural layout must correspond to that of the column and bearing wall systems through which its loads are transferred down to the foundation system. This pattern of roof supports and the extent of the roof spans, in turn, influences the layout of interior spaces and the type of ceiling that the roof structure may support. Long roof spans would open up a more flexible interior space while shorter roof spans might suggest more precisely defined spaces.



The form of a roof structure—whether flat or pitched, gabled or hipped, broad and sheltering, or rhythmically articulated—has a major impact on the image of a building. The roof may be exposed with its edges flush with or overhanging the exterior walls, or it may be concealed from view, hidden behind a parapet. If its underside remains exposed, the roof also transmits its form to the upper boundaries of the interior spaces below.

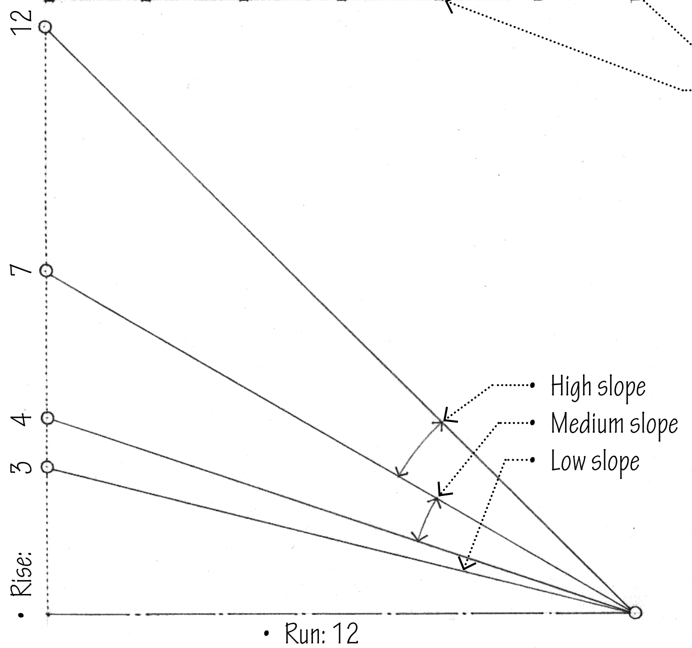




Flat Roofs

- Flat roofs require a continuous membrane roofing material.
- Minimum recommended slope: 1/4 in. per foot (1:50)
- The roof slope may be achieved by inclining the structural members or roof deck, or by tapering the layer of thermal insulation.
- The slope usually leads to interior drains; perimeter scuppers may be used as overflow drains.

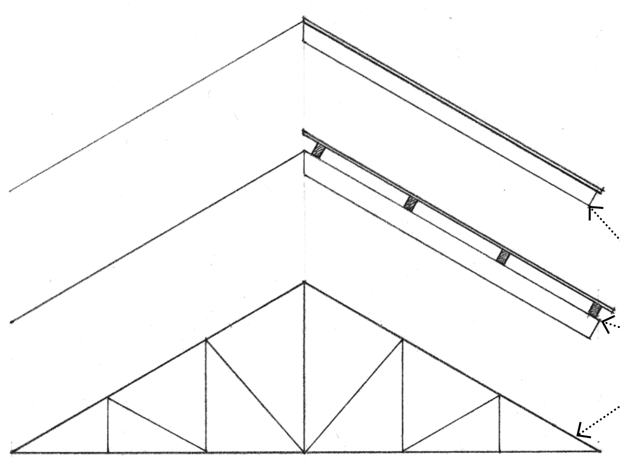
- Flat roofs can efficiently cover a building of any horizontal dimension, and may be structured and designed to serve as an outdoor space.
- The structure of a flat roof may consist of:
  - Reinforced concrete slabs
  - Flat timber or steel trusses
  - Timber or steel beams and decking
  - Wood or steel joists and sheathing



Sloping Roofs

- Sloping roofs may be categorized into
- Low-slope roofs—up to 3:12
- Medium- to high-slope roofs—4:12 to 12:12

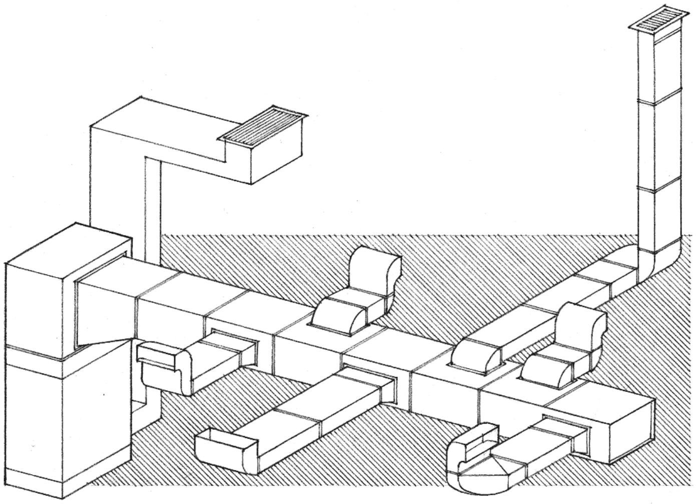
- The roof slope affects the choice of roofing material, the requirements for underlayment and eave flashing, and design wind loads.
- Low-slope roofs require roll or continuous membrane roofing; some shingles and sheet materials may be used on 3:12 pitches.
- Medium- and high-slope roofs may be covered with shingles, tiles, or sheet materials.
- Sloping roofs shed rainwater easily to eave gutters.



- The height and area of a sloping roof increase with its horizontal dimensions.
- The space under a sloping roof may be usable.
- Sloping roof planes may be combined to form a variety of roof forms.
- Sloping roofs may have a structure of:
  - Wood or steel rafters and sheathing
  - Timber or steel beams, purlins, and decking
  - Timber or steel trusses

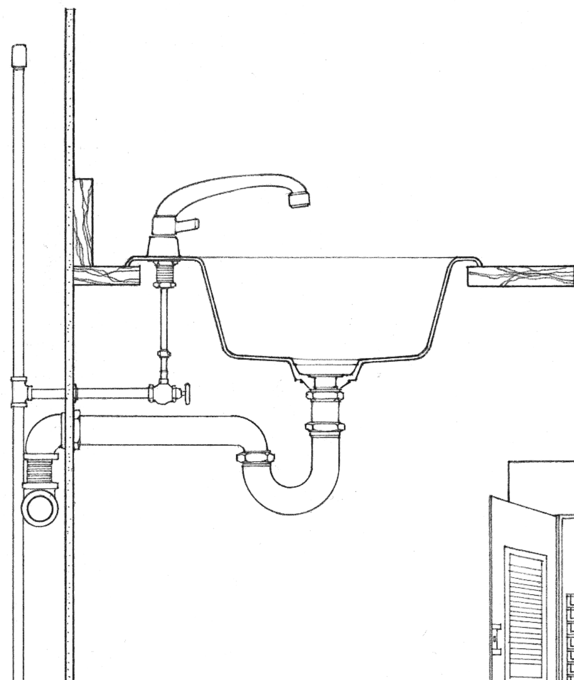
Mechanical and Electrical Systems

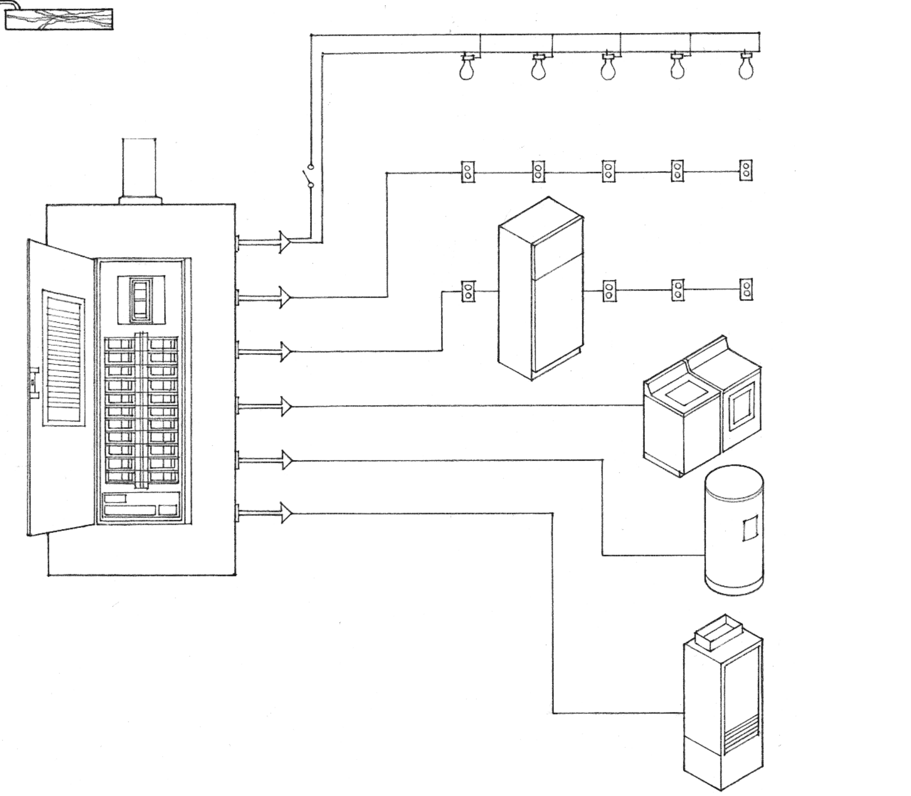
This section discusses the mechanical and electrical systems that are required to maintain the necessary conditions of environmental comfort, health, and safety for the occupants of a building. The intent is not to provide a complete design manual but to outline those factors that should be considered for the successful operation of these systems and their integration with other building systems.

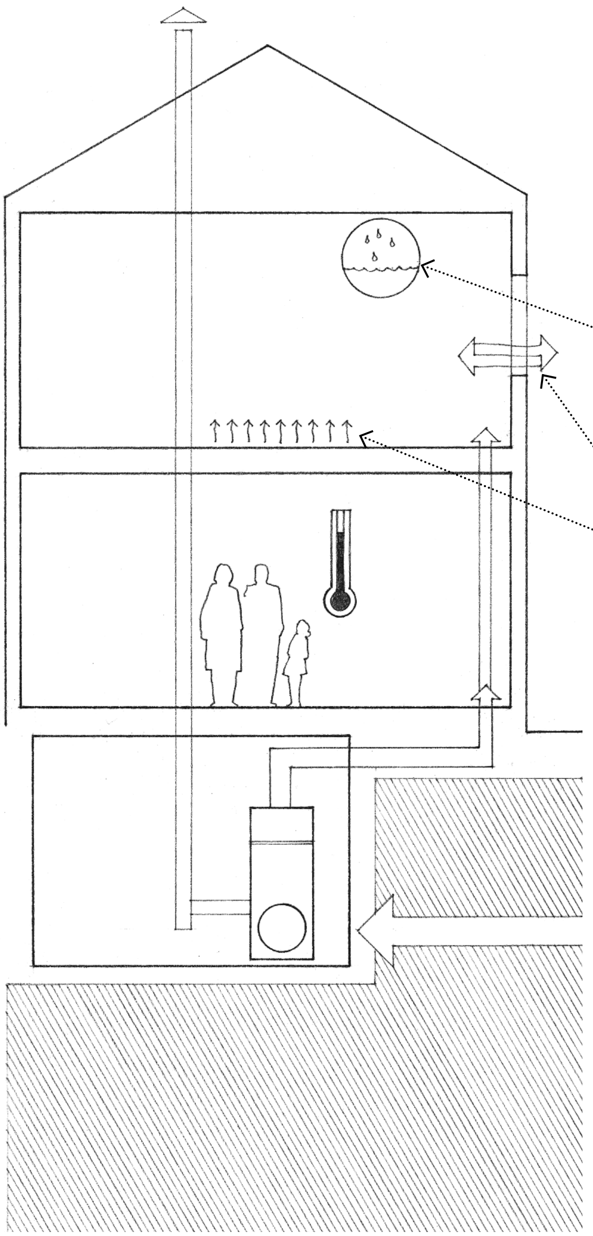


Heating, ventilating, and air-conditioning systems condition the interior spaces of a building for the environmental comfort of the occupants. A potable water supply is essential for human consumption and sanitation. The efficient disposal of fluid waste and organic matter is necessary in order to maintain sanitary conditions within a building and in the surrounding area. Electrical systems furnish light and heat for a building's occupants, and power to run its machines.

These systems require a significant amount of space. Because much of the hardware for these systems is normally hidden from view—within concealed construction spaces or special rooms—the layout of these systems should be carefully integrated with each other as well as with the structural and enclosure systems of the building.







Heating and Cooling Systems

The siting, orientation, and construction assemblies of a building should minimize heat loss to the outside in cold weather and minimize heat gain in hot weather. Any excessive heat loss or heat gain must be balanced by passive energy systems or by mechanical heating and cooling systems in order to maintain conditions of thermal comfort for the occupants of a building. While heating and cooling to control the air temperature of a space is perhaps the most basic and necessary function of a mechanical system, attention should be paid to the other three factors that affect human comfort— relative humidity, mean radiant temperature, and air motion.

- Relative humidity can be controlled by introducing water vapor through humidifying devices, or removing it by ventilation.
- Air motion can be controlled by natural or mechanical ventilation.
- The mean radiant temperature of room surfaces can be raised by using radiant heating panels or lowered by radiant cooling.

Heating and Cooling

- Air temperature is controlled by the supply of a fluid medium—warm or cool air, or hot or chilled water—to a space.
- Furnaces heat air; boilers heat water or produce steam; electric heaters employ resistance to convert electric energy into heat.
- The size of heating and cooling equipment required for a building is determined by the heating and cooling loads anticipated.

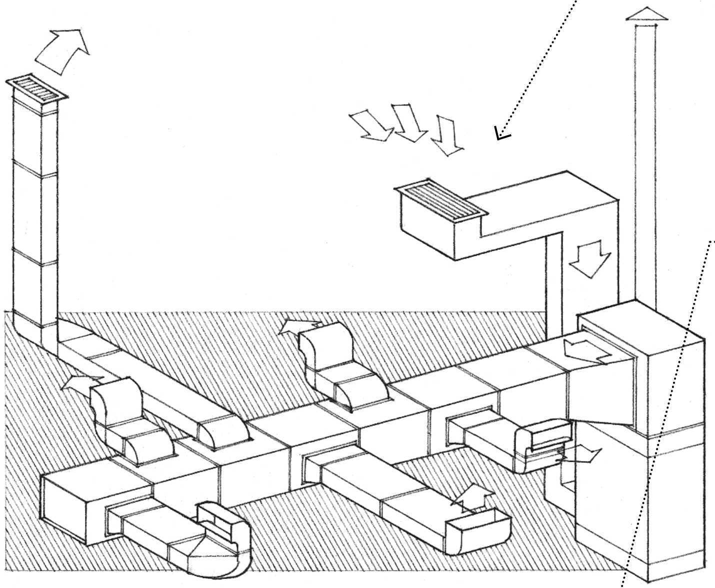
The traditional fossil fuels—gas, oil, and coal—continue to be the most commonly used to produce the energy for heating and cooling buildings. Natural gas burns cleanly and does not require storage or delivery except through a pipeline. Propane gas is also a clean-burning fuel that is slightly more expensive than natural gas. Oil is also an efficient fuel choice, but it requires delivery by trucks to storage tanks located in or near the point of utilization. Coal is rarely used for heating in new residential construction; its use fluctuates in commercial and industrial construction.

Electricity is a clean energy source requiring no combustion or fuel storage at the site. It is also a compact system, being distributed through small wires and using relatively small and quiet equipment. However, the cost to electrically heat or cool a building can be prohibitive and most electric power must be generated by utilizing other sources of energy—nuclear fission or the burning of fossil fuels—to drive turbines. Nuclear energy, despite continuing concerns with the safety of its installations and the disposal of nuclear waste material, may still become an important source of power. A small percentage of turbines are driven by flowing water (hydropower), wind, and the gases produced by burning natural gas, oil, and coal.

Of increasing concern are the uncertain cost and availability of conventional energy sources, the impact of energy extraction and production on environmental resources, and the burning of greenhouse-gas-emitting fossil fuels. Because more than 40% of all energy and more than 65% of all electricity in the United States are consumed in buildings, the design professions, construction industry, and governmental agencies are exploring strategies for reducing the energy consumption of buildings and evaluating alternative, renewable sources of energy: solar, wind, biomass, hydrogen, hydropower, ocean, and geothermal.

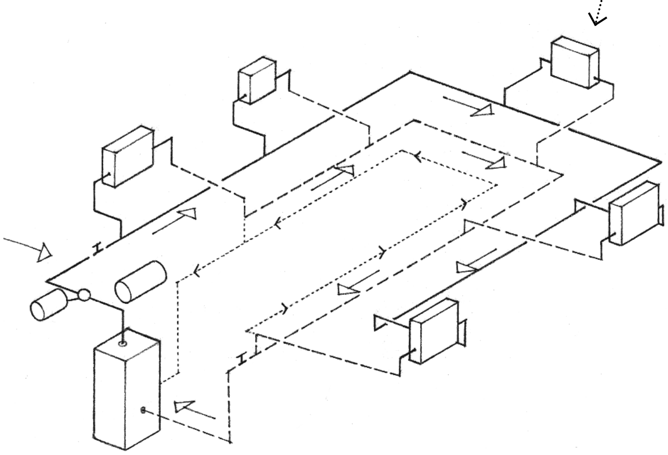
Forced-Air Heating

Forced-air heating is a system for heating by means of air heated in a gas, oil, or electric furnace and distributed by a fan through ductwork to registers or diffusers in inhabited spaces. It is the most versatile and widely used system for heating houses and small buildings.



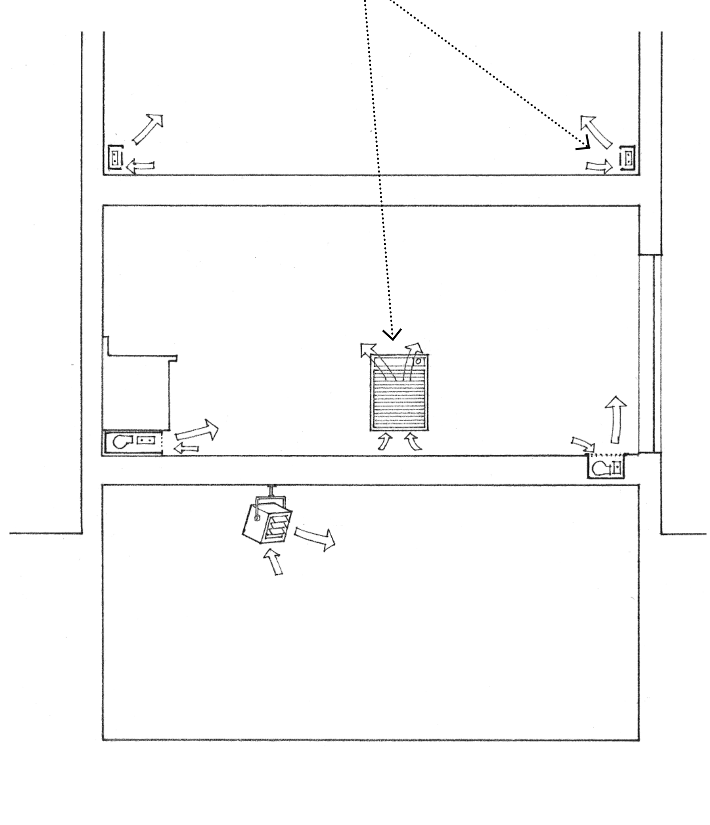
Hot-Water Heating

Hot-water or hydronic heating is a system for heating a building by means of water heated in a boiler and circulated by a pump through pipes to radiators or convectors. Steam heating is similar in principle, utilizing steam generated in a boiler and circulating it through piping to radiators. In large cities and building complexes, hot water or steam generated at a central boiler plant may be available via underground pipelines. This availability would eliminate the need for an on-site boiler.



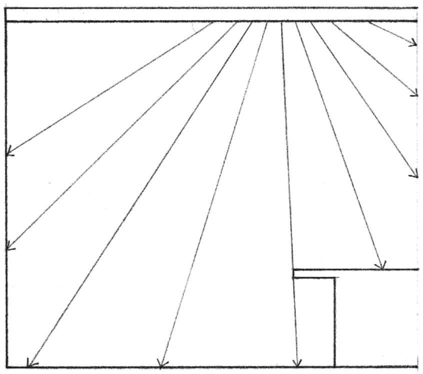
Electric Heating

Electric heating is more accurately described as electric-resistance heating. Resistance is the property of a conductor by virtue of which the passage of current is opposed, causing electric energy to be converted into heat. Electric-resistance heating elements may be exposed to the air stream in a furnace or ductwork in a forced-air heating system or provide the heat for a boiler in a hydronic heating system. More direct means of heating with electric energy involves housing the resistance wires or coils in space-heating units. While compact and versatile, these electric-resistance heaters have no provision for controlling humidity and air quality.



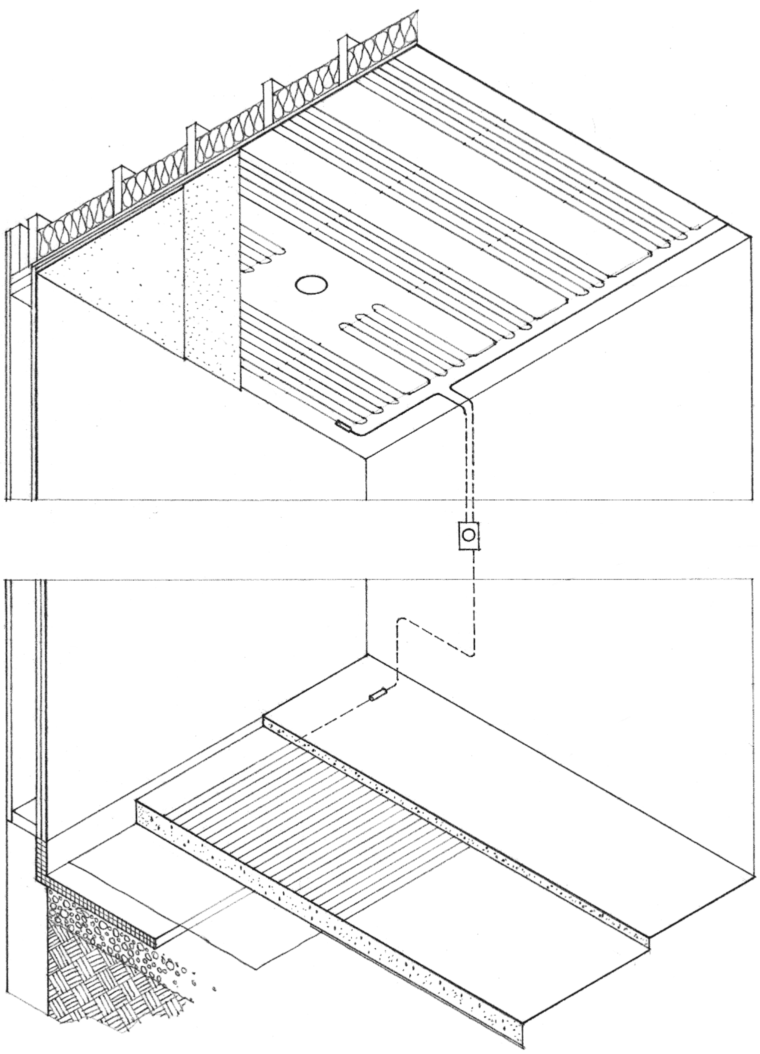
Radiant Heating

Radiant heating systems utilize heated ceilings, floors, and sometimes walls, as radiating surfaces. The heat source may be pipes or tubing carrying hot water or electric-resistance heating cables embedded within the ceiling, floor, or wall construction. The radiant heat is absorbed by surfaces and objects in the room, reradiates from the warmed surfaces, and raises the mean radiant temperature (MRT) as well as the ambient temperature in the space.



Radiant heat:

- Travels in a direct path;
- Cannot travel around corners and may therefore be obstructed by physical elements within the space, such as furniture;
- Cannot counteract cold downdrafts along exterior glass areas;
- Is not affected by air motion.



Floor installations are effective in warming concrete slabs. In general, however, ceiling installations are preferred because ceiling constructions have less thermal capacity and can respond faster. Ceiling panels can also be heated to a higher surface temperature than floor slabs. In both electric and hot-water radiant systems, the installations are completely concealed except for thermostats or balancing valves.

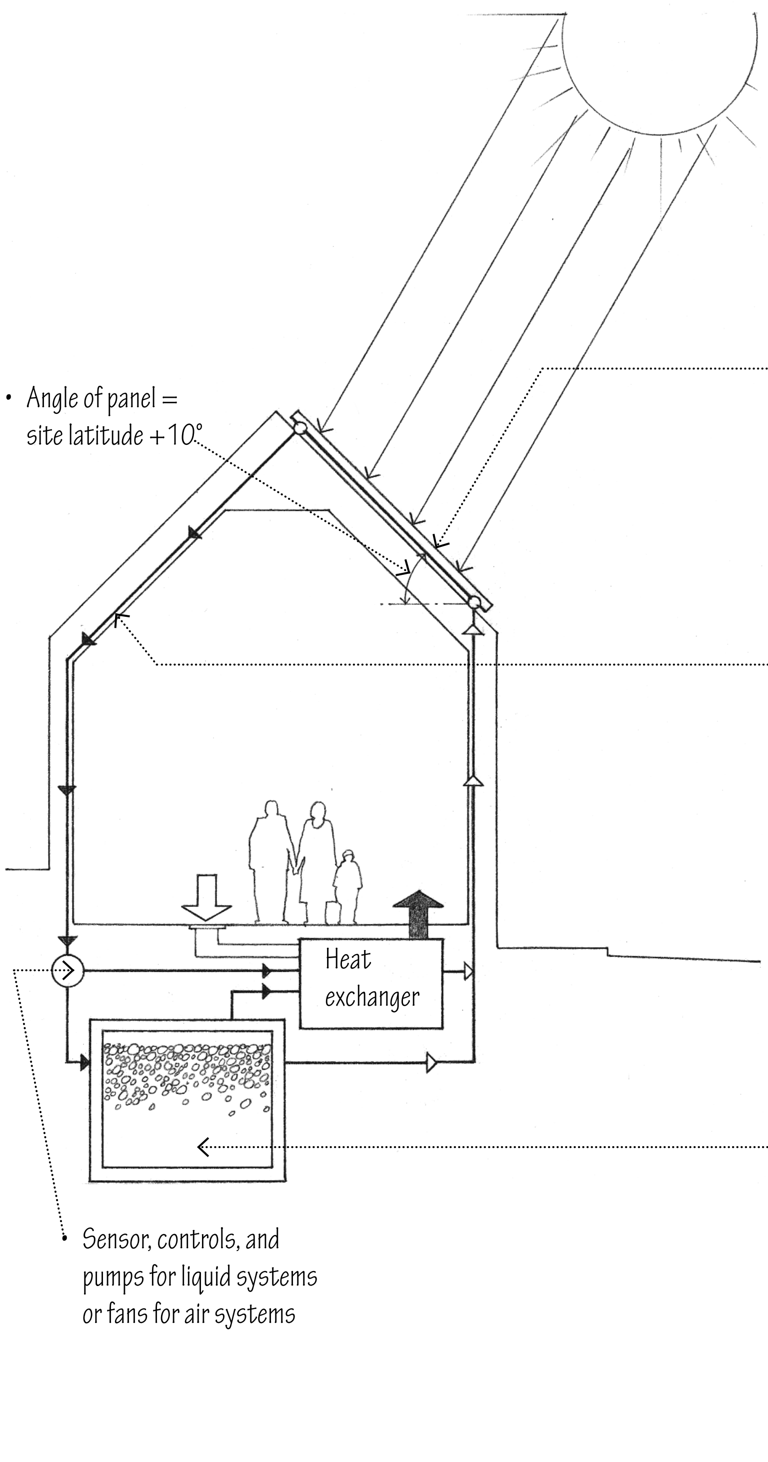
Because radiant panel heating systems cannot respond quickly to changing temperature demands, they may be supplemented with perimeter convector units. For complete air conditioning, separate ventilating, humidity control, and cooling systems are required.

Liquid radiant heating systems circulate warm water through metal or plastic pipes either encased in a concrete slab that serves as a thermal mass or secured to the underside of subflooring with conductive heat plates. The supply water may be heated in a boiler, heat pump, solar collector, or geothermal system. In response to the thermostat setting, a control valve adjusts the supply water temperature by mixing it with the circulating water from the pipe loops.

Solar Energy Systems

Active solar energy systems absorb, transfer, and store energy from solar radiation for building heating and cooling. They normally consist of the following components:

- Solar collector panels
- Circulation and distribution system for the heat transfer medium
- Heat exchanger and storage facility



Solar Collector Panels

- The solar collector panels should be oriented within 20° of true south and not be shaded by nearby structures, terrain, or trees. The required collector surface area depends on the heat exchange efficiency of the collector and heat transfer medium, and the heating and cooling load. Current recommendations range from 1/3 to 1/2 of the net floor area of the building.

Heat Transfer Medium

- The heat transfer medium may be air, water, or other liquid. It carries the collected heat energy from the solar panels to the heat exchange equipment or to a storage utility for later use.
- Liquid systems use pipes for circulation and distribution. An antifreeze solution provides freeze protection; a corrosion-retarding additive is required for aluminum pipes.
- The ductwork for air systems requires more installation space. Larger collector surfaces are also required since the heat transfer coefficient for air is less than that of liquids. The construction of the collector panels, however, is simpler and not subject to problems of freezing, leakage, and corrosion.

Storage Facility

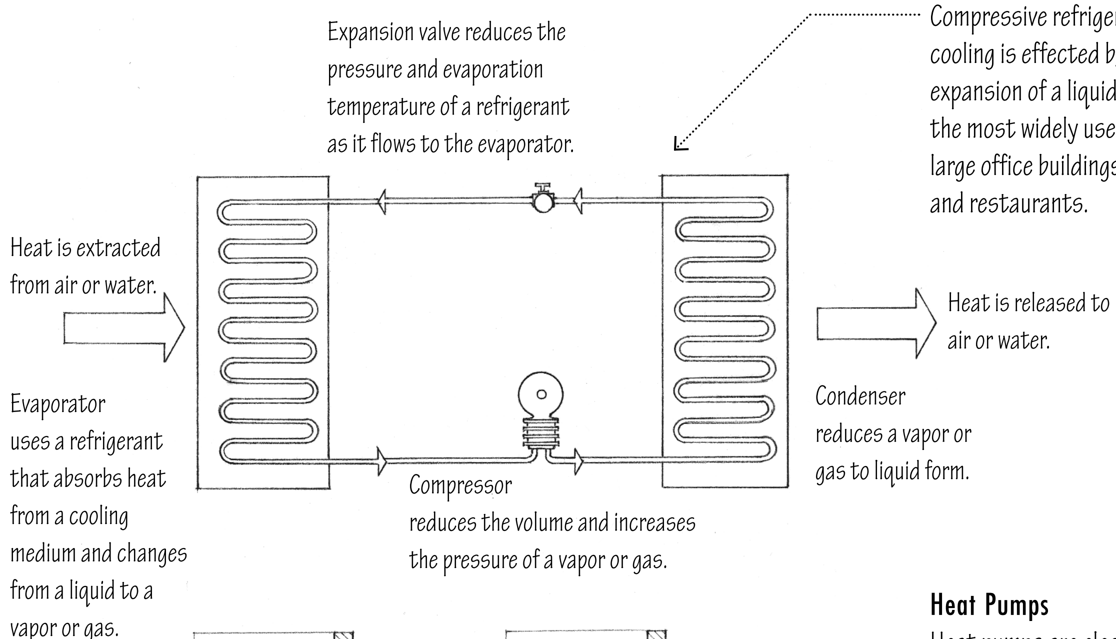
- An insulated storage facility holds heat for use at night or on overcast days. It may be in the form of a tank filled with water or other liquid medium, or a bin of rocks or phase-change salts for air systems.

- The heat distributing components of the solar energy system are similar to those of conventional systems.
- Heat may be delivered by an all-air or an air-water system.
- For cooling, a heat pump or absorption cooling unit is required.
- A backup heating system is recommended.

- For an active solar energy system to be efficient, the building itself must be thermally efficient and well insulated. Its siting, orientation, and window openings should take advantage of the seasonal solar radiation.

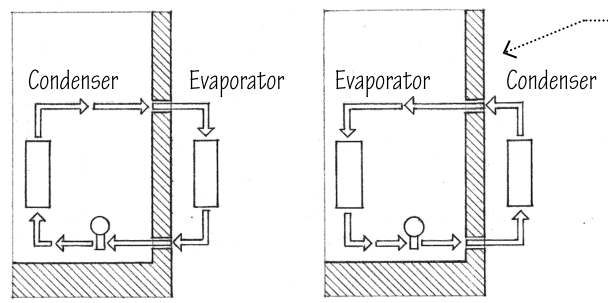
Compressive Refrigeration

Compressive refrigeration is a process in which cooling is effected by the vaporization and expansion of a liquid refrigerant. It is probably the most widely used method for air-conditioning large office buildings, hotels, hospitals, theaters, and restaurants.



Heat Pumps

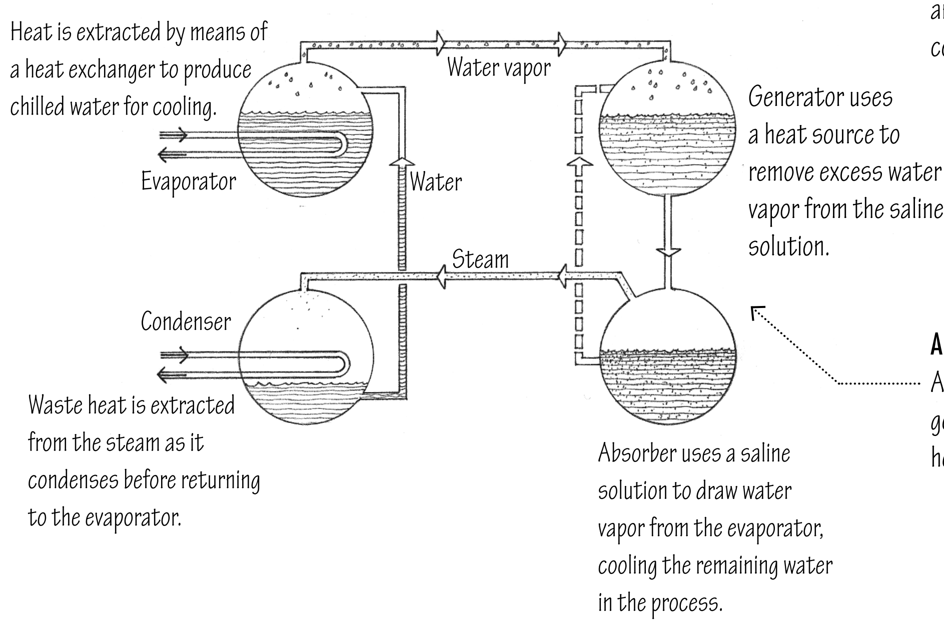
Heat pumps are electrically powered heating and cooling units. For cooling, the normal compressive refrigeration cycle is used to absorb and transfer excess heat to the outdoors. For heating, heat energy is drawn from the outdoor air by reversing the cooling cycle and switching the heat exchange functions of the condenser and evaporator. Heat pumps are most efficient in moderate climates where heating and cooling loads are almost equal. In freezing temperatures, a heat pump requires an electric resistance heater to keep the outdoor coils from freezing.



Winter Heating **Summer Cooling**

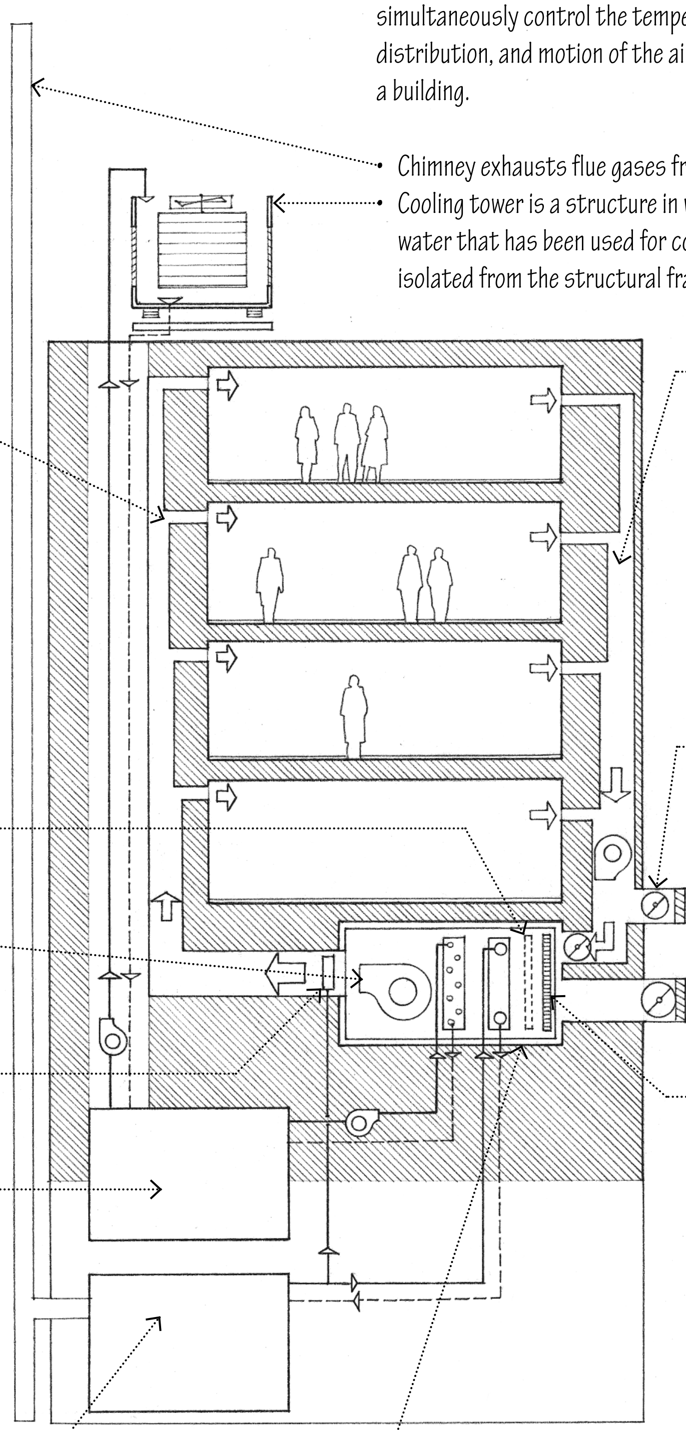
Absorption Refrigeration

Absorption refrigeration uses an absorber and a generator instead of a compressor to transfer heat and produce cooling.



HVAC systems

Heating, ventilating, and air conditioning (HVAC) systems simultaneously control the temperature, humidity, purity, distribution, and motion of the air in the interior spaces of a building.



- Chimney exhausts flue gases from the burning of fuel.
- Cooling tower is a structure in which heat is extracted from water that has been used for cooling. It should be acoustically isolated from the structural frame of the building.
- Heating and cooling energy can be distributed by air, water, or a combination of both.
- Return air is conveyed from an air-conditioned space back to the central plant for processing and recirculation.
- Preheaters heat air that is below 32°F (0°C) to a temperature slightly above freezing, in advance of other processing.
- Dampers regulate the draft in air ducts, intakes, and outlets.
- Exhaust air
- Blowers supply air at a moderate pressure.
- Fresh air
- Humidifiers maintain or increase the amount of water vapor in the supply air.
- Filters remove suspended impurities from the air supply.
- Over half of indoor air quality problems result from inadequate ventilation and filtration. Building codes specify the amount of ventilation required for certain uses and occupancies in air changes per hour or in cubic feet per minute per person.
- Chilled water plant, powered by electricity, steam, or gas, delivers chilled water to the air handling equipment for cooling, and pumps condenser water to the cooling tower for the disposal of heat.
- Boiler produces hot water or steam for heating. Boilers require fuel (gas or oil) and an air supply for combustion. Oil-fired boilers also need an on-site storage tank.
- Fan room contains the air handling equipment in large buildings.
- Air-handling units contain the fans, filters, and other components necessary to treat and distribute conditioned air.

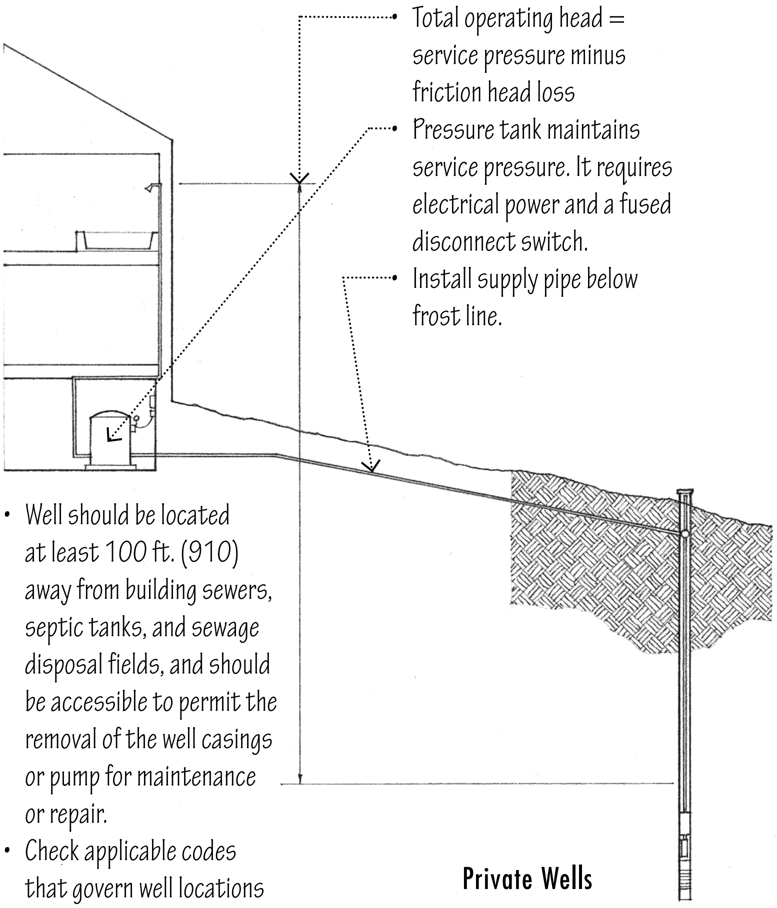
Water Supply Systems

Water is utilized in a building in the following ways:

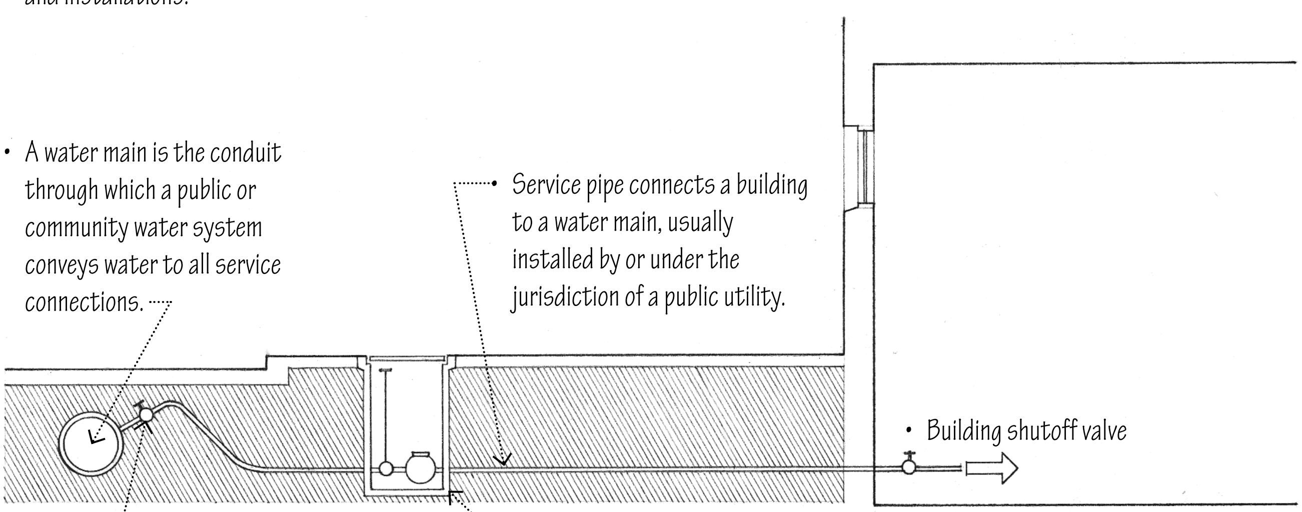
- Water is consumed by drinking, cooking, and washing.
- HVAC systems circulate water for heating and cooling, and maintaining a desirable level of humidity.
- Fire protection systems store water for extinguishing fires.

Water must be supplied to a building in the correct quantity, and at the proper flow rate, pressure and temperature, to satisfy the above requirements. For human consumption, water must be potable—free of harmful bacteria—and palatable. To avoid the clogging or corrosion of pipes and equipment, water may have to be treated for hardness or excessive acidity.

If water is supplied by a municipal or public system, there can be no direct control over the quantity or quality of water supplied until it reaches the building site. If a public water system is not available, then either drilled or bored wells or rainwater storage tanks are required.
Well water, if the source is deep enough, is usually pure, cool, and free of discoloration and taste or odor problems. A sample should be checked for bacteria and chemical content by the local health department before a well is put into operation.



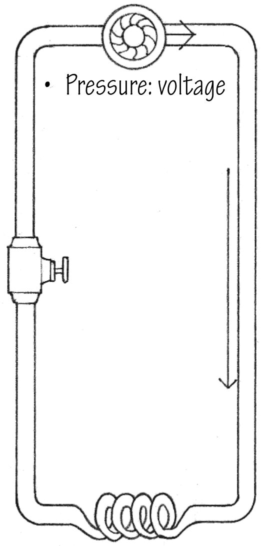
Private Wells



Public Water Supply

Hydraulic Analogy to Electric Circuit

Electrical energy flows through a conductor because of a difference in electrical charge between two points in a circuit.

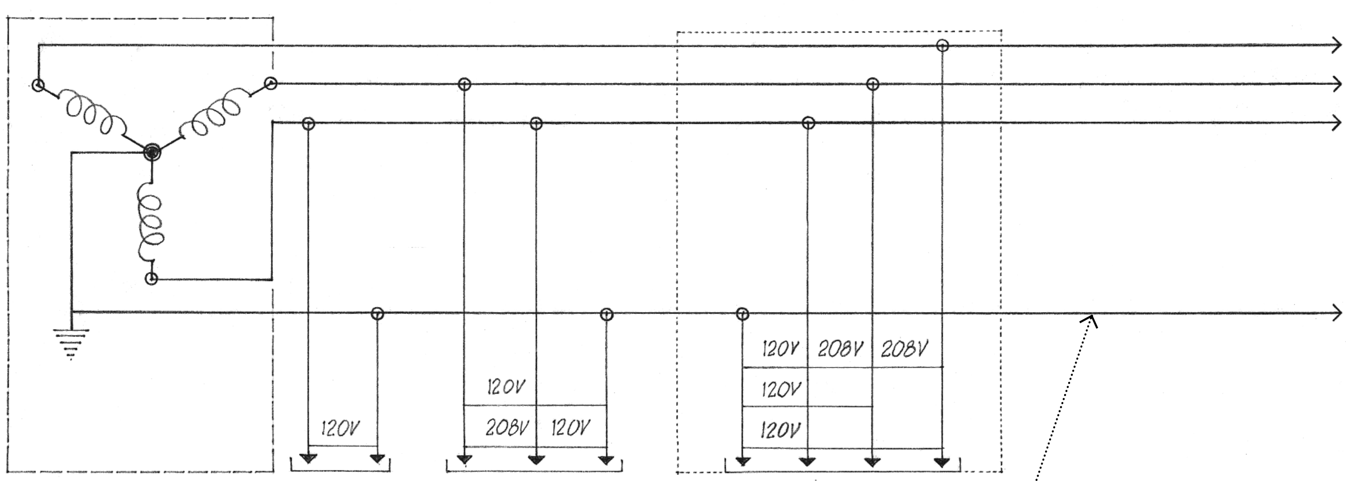


Electric Power

The electrical system of a building supplies power for lighting, heating, and the operation of electrical equipment and appliances. This system must be installed according to the building and electrical codes in order to operate safely, reliably, and effectively.

- Volt (V) is the SI unit of electromotive force, defined as the difference of electric potential between two points of a conductor carrying a constant current of one ampere, when the power dissipated between the points is equal to 1 watt.
- Ampere (A) is the basic SI unit of electric current, equivalent to a flow of one coulomb per second or to the steady current produced by 1 volt applied across a resistance of 1 ohm.
- Watt (W) is the SI unit of power, equal to 1 joule per second or to the power represented by a current of1 ampere flowing across a potential difference of 1 volt.
- Ohm is the SI unit of electrical resistance, equal to the resistance of a conductor in which a potential difference of one volt produces a current of one ampere. Symbol: Ω

Power is usually supplied to a building by the electric utility company. The schematic diagram that follows illustrates several voltage systems that may be furnished by the public utility according to the load requirements of a building. A large installation may use its own transformer to step down from a more economical, higher supply voltage to the service voltage. Generator sets may be required to supply emergency electrical power for exit lighting, alarm systems, elevators, telephone systems, fire pumps, and medical equipment in hospitals.



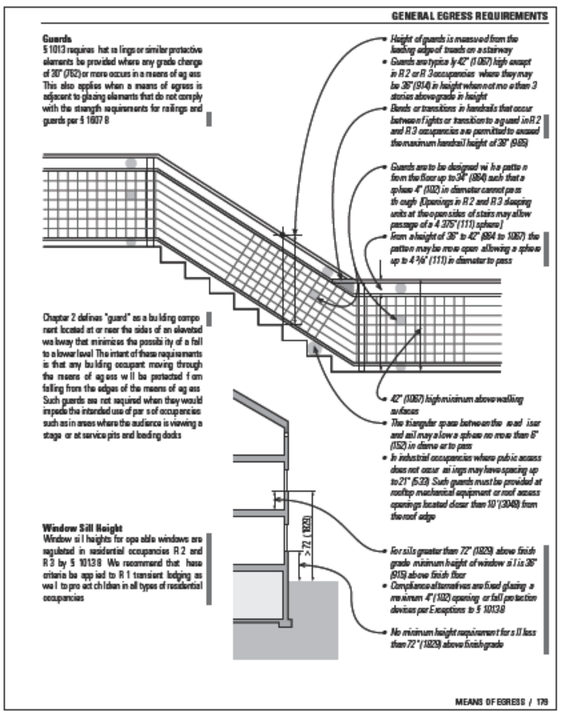
- Utility company transformer

- 120 V, single phase, two wire
- 120/208 V, single phase, three wire
- 120/240 V, single phase, three wire service is more common for residences.

- 120/208 V, three phase, four wire
- This service can be used by all but the largest installations which require higher voltages.

- Grounded neutral
- All electrical systems must be grounded to provide protection against shock and electrical fires.

13 Architectural Practice and Communication



What Are the Responsibilities of a Professional Architect?

In addition to building design, the architect is responsible for making sure that a building project adheres to building codes. The architect also coordinates those involved in design, engineering, and construction of a project along with the inspectors of any local government. Throughout this process, the architect advocates for the client, making sure that decisions made by various parties involved in design and construction do not compromise those aspects of a project that are important to the client.

In order to accomplish these tasks, the architect must clearly communicate to all involved parties. Specific kinds of drawings are the primary way this is done. In previous chapters, drawing has been discussed for its potential to generate and communicate design ideas. This chapter will discuss technical drawing as a means of communicating precise architectural information toward the realization of a project. These documents enable those involved with the design and construction of a project to communicate using one common graphic language that clearly illustrates the characteristics of a building and the manner in which it should be built.

The documents are often referred to as construction documents. They are used in the following ways:

- Architects use them to communicate the formal and spatial characteristics of the building.
- Structural engineers will use them to calculate the size and arrangement of structural elements.
- Mechanical, electrical, and plumbing engineers will use them to design the building's mechanical systems.
- Contractors will use them as a guide for the actual construction of the project.
- Building inspectors will use them to evaluate the building's compliance with local, state, national, and international building codes.

This chapter provides an overview of building code as the legal obligations of architecture. It also addresses the various drawing types typically included in a set of construction documents as a means of communicating the building's characteristics to those responsible for its development and construction.

"If a builder build a house for some one, and does not construct it properly, and the house which he built fall in and kill its owner, then that builder shall be put to death.

If it kill the son of the owner, the son of that builder shall be put to death.

If it kill a slave of the owner, then he shall pay slave for slave to the owner of the house.

If it ruin goods, he shall make compensation for all that has been ruined, and inasmuch as he did not construct properly this house which he built and it fell, he shall re-erect the house from his own means.

If a builder build a house for some one, even though he has not yet completed it; if then the walls seem toppling, the builder must make the walls solid from his own means."

Laws 229–233
Hammurabi's *Code of Laws*
(ca. 1780 BCE)

Building Codes

Building codes provide an ever-present set of boundaries to guide architectural design. They exist to set standards for architecture in a wide array of categories.

Building codes exist to ensure that buildings:

- Are safe to occupy
- Are accessible and usable to people with disabilities
- Conform to standards of value, appearance, and usage established by neighboring buildings

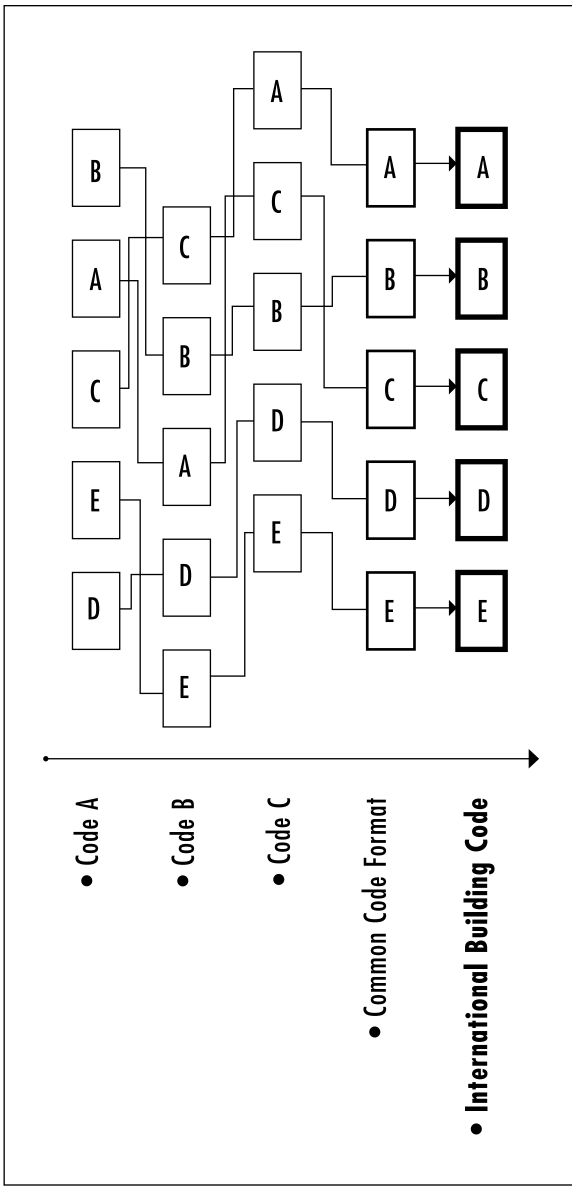
Three model-code groups published different building codes previously in widespread use in the United States. These codes were developed by regional organizations of building officials, building materials experts, design professionals, and life-safety experts to provide communities and governments with standard construction criteria for uniform application and enforcement. The ICBO Uniform Building Code was used primarily west of the Mississippi River and was the most widely applied of the model codes. The BOCA National Building Code was used primarily in the north-central and northeastern states. The SBCCI Standard Building Code was used primarily in the Southeast. The model-code groups have merged to form the International Code Council and BOCA, ICBO and SBCCI have ceased maintaining and publishing their legacy codes.

BUILDING CODE

Webster's Third New International Dictionary defines a building code as: "A set of rules of procedure and standards of materials designed to secure uniformity and protect the public interest in such matters as building construction and public health, established usually by a public agency and commonly having the force of law in a particular jurisdiction."

The International Building Code

Over the past few years, a real revolution has taken place in the development of model codes. There was recognition in the early 1990s that the nation would be best served by a comprehensive, coordinated, national model building code developed through a general consensus of code writers. There was also recognition that it would take time to reconcile the differences among the existing codes. To begin the reconciliation process, the three model codes were reformatted into a common format. The International Code Council, made up of representatives from the three model-code groups, was formed in 1994 to develop a single model code, using the information contained in the three current model codes. While detailed requirements still varied from code to code, the organization of each code became essentially the same during the mid-1990s. This allowed direct comparison of requirements in each code for similar design situations.



Numerous drafts of the new International Building Code were reviewed by the model-code agencies along with code users. From that multiyear review grew the original edition of the International Building Code (IBC), first published in 2000. There is now a single national model code, maintained by a group comprising representatives of the prior three model-code agencies, the International Code Council, headquartered in Washington, D.C. The three organizations have now accomplished a full merger of the three model-code groups into a single agency to update and maintain the IBC.

Note that, in addition to the International Building Code (IBC) code, designers should be familiar with the International Residential Code (IRC). This code is meant to regulate construction of detached one- and two-family dwellings and townhouses that are not more than three stories in height. This code supplants residential requirements in the IBC in jurisdictions where it is adopted.

Note also that most local jurisdictions make other modifications to the codes in use in their communities. For example, many jurisdictions make amendments to require fire sprinkler systems where they may be optional in the model codes. In such cases, mandatory sprinkler requirements may change the design trade-offs offered in the model code for inclusion of sprinklers where "not otherwise required" by the code. It is imperative that the designer determine what local adoptions and amendments have been made to be certain which codes apply to a specific project.

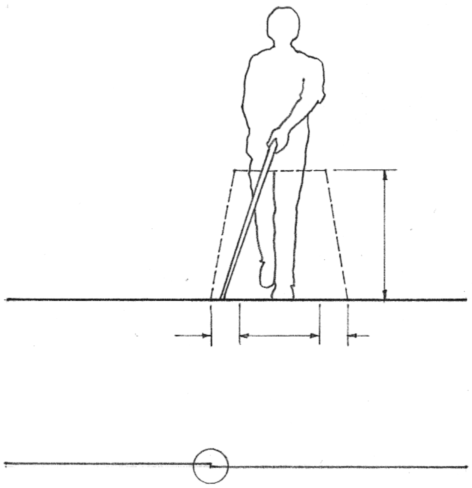
Federal and National Building Codes

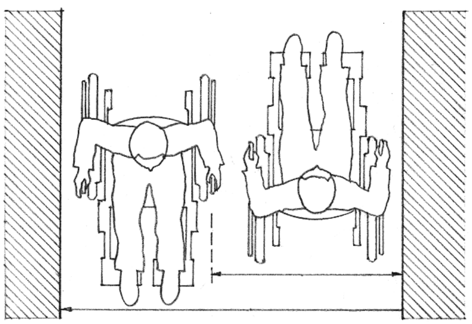
There are also specific federal requirements that must be considered in design and construction in addition to the locally adopted version of the model codes. Among these are the Americans with Disabilities Act of 1990 and the Federal Fair Housing Act of 1988.

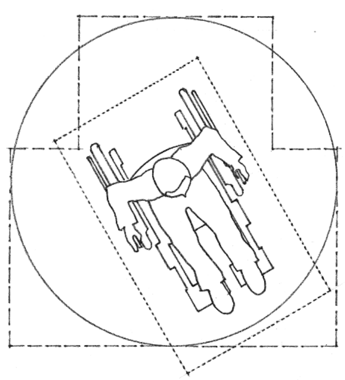
Americans with Disabilities Act

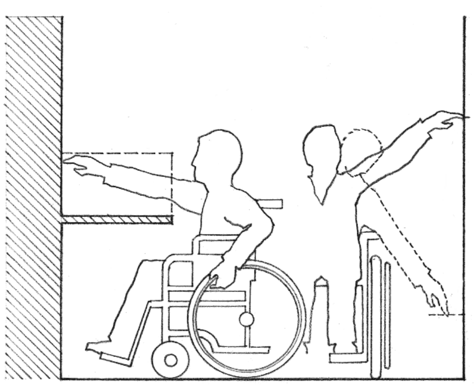
The Americans with Disabilities Act (ADA) of 1990 is federal civil rights legislation requiring that buildings be made accessible to persons with physical disabilities and certain defined mental disabilities. The ADA Accessibility Guidelines (ADAAG) are administered by the Architectural and Transportation Barriers Compliance Board (ATBCB), and the regulations are administered by the U.S. Department of Justice. Enforcement of the law is accomplished through legal actions brought by individuals or groups asserting violations of their rights of access, as civil rights. A new version of the ADA accessibility guidelines known as the ADA/ABA Accessibility Guidelines went into effect on March 15, 2012.

It is critical for designers to understand that the ADA is not subject to interpretation by local building officials; it is enforced by legal action, through the courts. Access is to be provided for all disabilities, not just for people with mobility impairments. These include hearing, vision, speech, and cognitive impairments, as well as persons of short stature and with limited mobility not necessarily requiring the use of a wheelchair. The ADA applies to all new construction. The ADA also requires that barriers to access be removed from existing buildings where such work is readily achievable. The definition of readily achievable is an economic one and should be addressed by the building's owner, not by the building's architect.









The ADA is one of the few building regulations—in this case a law, not a code—that requires retrofitting of projects apart from upgrading facilities during remodeling or renovation. Most codes apply to existing buildings only when renovation is undertaken. Under the ADA, those access improvements that are readily achievable should be undertaken by the owner whether or not any other remodeling work is to be done. The owner, not the architect, must make this determination.

Because the ADA is not enforced by local building officials, designers should concentrate on those accessibility codes and standards that are enforced locally and are subject to review and interpretation as part of the permitting process. It is also prudent to review design work against ADAAG at the same time as the model-code review. It is often a judgment call as to which is the most stringent requirement where requirements between codes and legislation differ. In these situations, it is essential and prudent to make clients aware of these discrepancies and have them actively participate in any decisions as to which part of which requirements will govern the design of project components.

Space requirements for accessibility are related to ergonomics. Bigger is not automatically better. The 18 in. (455) dimension between a toilet and adjacent grab bars is based on reach ranges and leverage for movement using one's arms. A longer reach reduces leverage and, thus, may be worse than too little space.

Federal Fair Housing Act

The Federal Fair Housing Act (FFHA) of 1988 includes Department of Housing and Urban Development (HUD) regulations requiring all residential complexes of four or more dwelling units constructed after March 13, 1991 to be adaptable for use by persons with disabilities. For example, residential complexes must provide access to all units on the ground floor, and all units must be accessible from grade by a ramp or elevator. Many state housing codes also incorporate these requirements.

State Building Codes

Each state has a separate and distinct code adoption process. In the past, many states adopted one of the three previous model codes, and some states even had their own building codes. The geographic areas for state model-code adoptions corresponded roughly to the areas of influence of the three previous model codes. The BOCA National Building Code predominated in the northeastern United States. The Southern Building Code was adopted throughout the southeastern United States. The Uniform Building Code was adopted in most states west of the Mississippi River. Many states allowed local adoption of codes so that in some states, such as Texas, adjacent jurisdictions in the same state had different building codes based on different model codes. Now, the advent of the International Codes has altered this landscape drastically. The "I Codes" are now the basic model codes in essentially every state. However, be aware that most state processes still allow amendments to the IBC, which means that there will likely be state-adopted amendments to the IBC. Make certain you know what code you are working with at the permitting level.

Local Building Codes

Many localities adopt the model-code documents with little modification except for the administrative chapters that relate to local operations of the building department. Larger cities, such as Los Angeles, New York City, Chicago, and San Francisco, typically adopt much more sweeping revisions to the model codes. The codes for such cities often bear little resemblance to the underlying model codes, and in some cases have no basis in them at all. Interpretations, even of the unaltered model code made by big-city building departments, often tend to be very idiosyncratic and nonuniform when compared to smaller jurisdictions that use less modified versions of the model codes. The adoption of the IBC at the state level has generated a review of big-city building codes so that these city codes are moving toward greater conformity with the model codes. For example, San Francisco and Los Angeles previously used a UBC-based state code, which has now been converted to an IBC-based, locally modified state code. This will require a careful analysis of the city-code amendments for conformance with the new model code. This redevelopment of codes has also been occurring in other large cities, such as Dallas and New York, as their states adopt the IBC. Be aware of local modifications and be prepared for varying interpretations of the same code sections among various jurisdictions. Do not proceed too far in the design process based on review of similar designs in another jurisdiction without verification of the code interpretation in the jurisdiction where the project is located.

Other Codes

There are also a number of other codes that the designer must be familiar with. They are mentioned here in brief to remind users of the International Building Code that other documents must be consulted during project design.

Among these specialized codes is the Life Safety Code (NFPA-101) published by the National Fire Protection Association. This code serves as a basis for the egress provisions in the other model codes. Designers may encounter NFPA-101 when doing federal and hospital work. The NFPA also publishes various other documents that are adopted to accompany the other model codes. Primary examples are NFPA-13, which governs the installation of fire sprinklers, and NFPA-70, which is the National Electric Code.

Recently the National Fire Protection Association completed development of a new model building code, NFPA 5000, to rival the International Building Code. The development of this code is meant to offer an alternative to the "I" codes. The NFPA 5000 has, to date, been adopted in very few jurisdictions. Some jurisdictions may move to adopt either the International code family or the NFPA family of codes, or even portions of each. This is yet another reason for designers to verify in detail what model code documents are adopted by the authorities having jurisdiction (AHJ)—a catch-all phrase for all planning, zoning, fire, and building officials who have something to say about building—where a project is located.

Fire codes are typically considered maintenance codes. They are intended to provide for public health and safety in the day-to-day operation of a structure. They are also meant to ensure that building life-safety systems remain operational in case of emergency. The various model-code agencies have developed model fire codes for these purposes. They are developed with primary input from the fire services and less input from design professionals. Note, however, that fire codes can have an impact on building design. They contain requirements for fire-truck access, locations and spacing of fire extinguishers, as well as requirements for sprinklers and wet or dry standpipes. The fire code also may contain requirements for added fire protection related to the ease or difficulty of fire equipment access to structures.

Plumbing codes often dictate the number of plumbing fixtures required in various occupancies. Some codes place this information in the building code, some in the plumbing code, and some in appendices that allow local determination of where these requirements may occur in the codes. The designer must determine which course of legal adoption the local authority has chosen. The determination of the required number of plumbing fixtures is an important design consideration. It is essential to use the adopted tables and not automatically assume those in the building code apply.

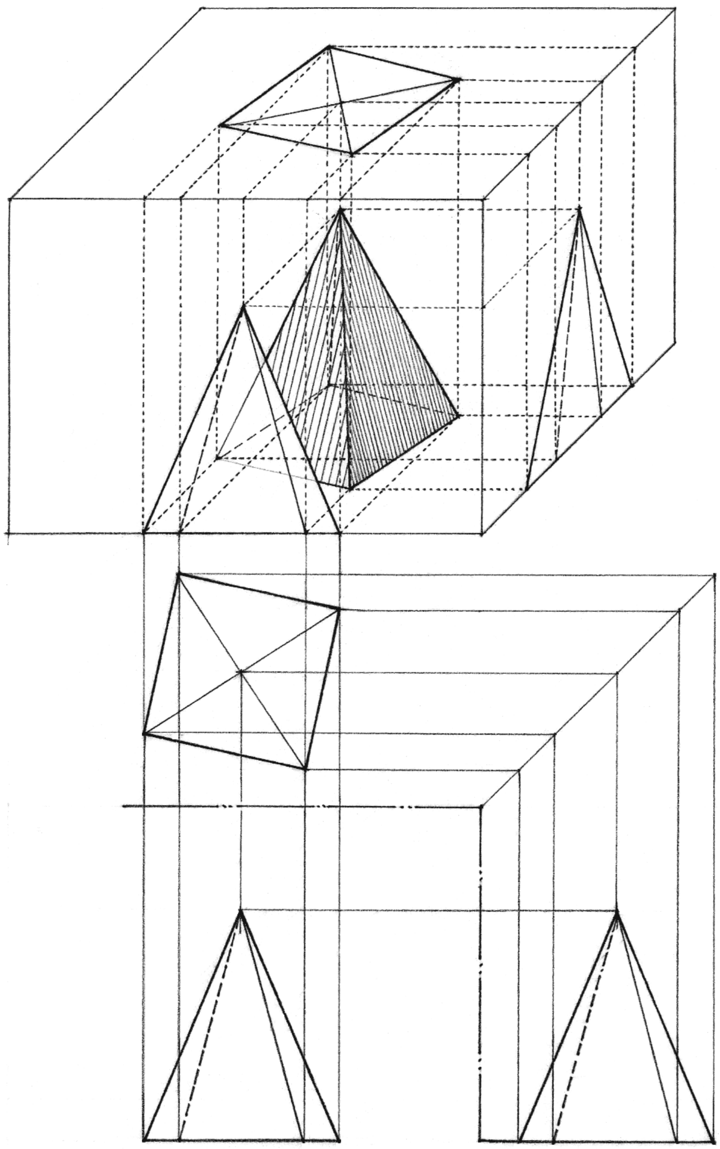
Standard of Care

The designer should always remember that codes are legally and ethically considered to be minimum criteria that must be met by the design and construction community. The protection of health, safety, and welfare is the goal of these minimum standards. Registered design professionals will be held by legal and ethical precedents to a much higher standard than the code minimum.

The so-called "standard of care" is a legal term defining the level of quality of service that a practitioner is expected to meet. This is higher than the minimum standard defined by the code. The code is the level that a practitioner must never go below. Because professional work involves judgment, perfection is not expected of a design professional. The standard of care is defined for an individual designer as being those actions that any other well-informed practitioner would have taken given the same level of knowledge in the same situation. It is a relative measure, not an absolute one.

Life Safety vs. Property Protection

The basis for building-code development is to safeguard the health, safety, and welfare of the public. The first and foremost goal of building codes is the protection of human life from the failure of life-safety provisions in a building, or from structural collapse. There is also a strong component of property protection contained in code requirements. Sprinkler provisions can serve both purposes. When buildings are occupied, sprinklers can contain or extinguish a fire, allowing the building occupants to escape. The same sprinkler system can protect an unoccupied structure from loss if a fire occurs when the structure is not occupied. While many systems may perform both life safety and property protection functions, it is essential that code developers keep the issue of life safety versus property protection in mind. For example, security measures to prevent intrusion into a structure may become hazards to life safety. A prime example of this is burglar bars on the exterior of ground-floor windows that can trap inhabitants of the building in an emergency if there is not an interior release to allow occupants to escape while still maintaining the desired security. In no case should property-protection considerations have primacy over life safety.



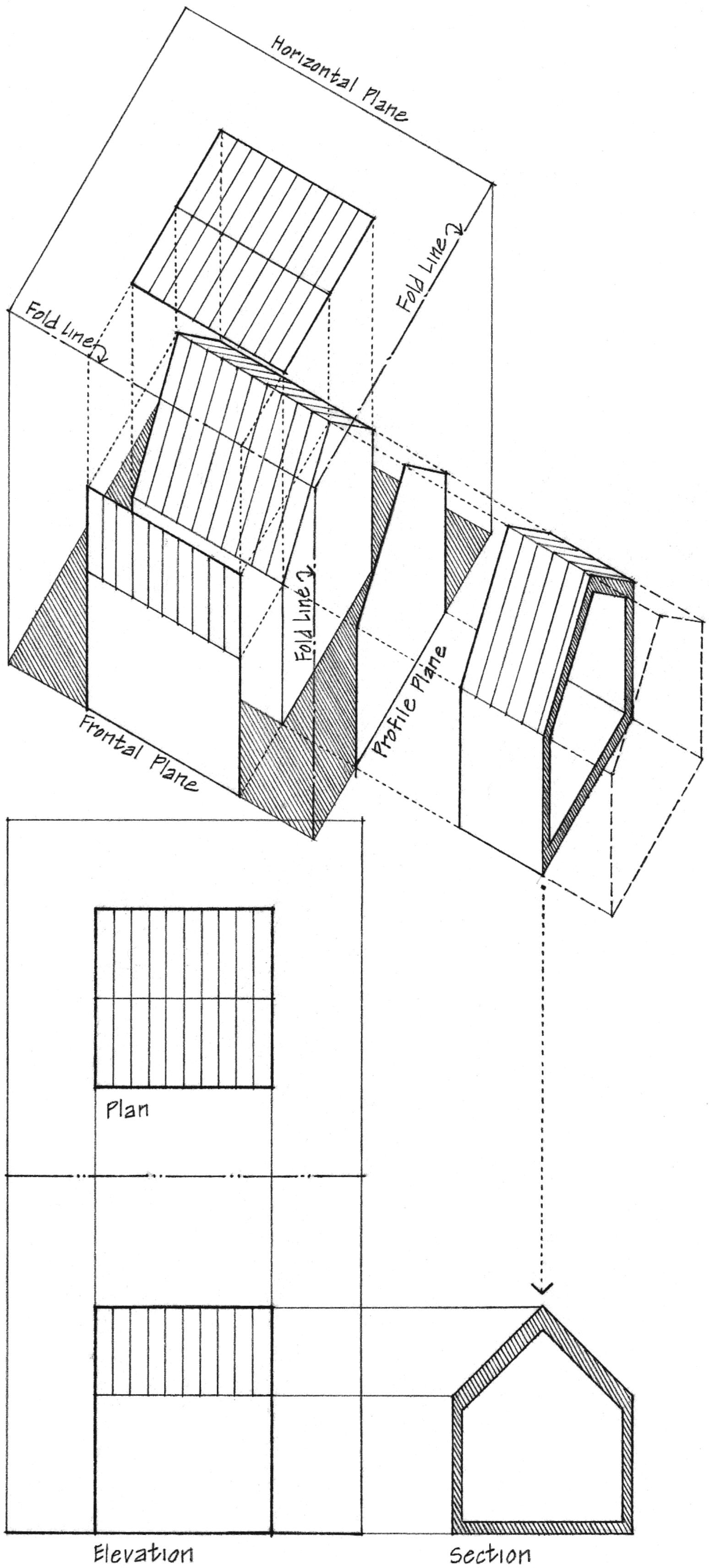
Multiview Drawings

Multiview drawings comprise the drawing types we know as plans, elevations, and sections. Each is an orthographic projection of a particular aspect of an object or construction. These orthographic views are abstract in the sense that they do not match optical reality. They are a conceptual form of representation based on what we know about something rather than on the way it is seen from a point in space. There is no reference to an observer, or if there is, the spectator's eye is an infinite distance away.

In orthographic projection, parallel projectors meet the picture plane at right angles. Therefore, the orthographic projection of any feature or element that is parallel to the picture plane remains true in size, shape, and configuration. This gives rise to the principal advantage of multiview drawings—the ability to precisely locate points, gauge the length and slope of lines, and describe the shape and extent of planes.

During the design process, multiview drawings establish two-dimensional planar fields on which we can study formal patterns and scale relationships in a composition, as well as impose an intellectual order on a design. The ability to regulate size, placement, and configuration also makes multiview drawings useful in communicating the graphic information necessary for the description, fabrication, and construction of a design.

On the other hand, a single multiview drawing can only reveal partial information about an object or construction. There is an inherent ambiguity of depth as the third dimension is flattened onto the picture plane. Whatever depth we read in a solitary plan, section, or elevation must be implied by such graphic depth cues as hierarchical line weights and contrasting tonal values. While a sense of depth can be inferred, it can be known with certainty only by looking at additional views. We, therefore, require a series of distinct but related views to fully describe the three-dimensional nature of a form or composition—hence the term multiview.



Orthographic Views

If we enclose an object within a transparent picture-plane box, we can name the principal picture planes and the images projected orthographically onto these planes. Each orthographic view represents a different orientation and a particular vantage point from which to view the object. Each plays a specific role in the development and communication of a design.

Principal Planes

A principal plane is any of a set of mutually perpendicular picture planes on which the image of an object is projected orthographically.

Horizontal Plane

A horizontal plane is the principal level picture plane on which a plan or top view is projected orthographically.

Frontal Plane

A frontal plane is the principal vertical picture plane on which an elevation or front view is projected orthographically.

Profile Plane

A profile plane is the principal vertical picture plane on which a side or end view is projected orthographically.

Fold Line

A fold line is the trace representing the intersection of two perpendicular picture planes.

Principal Views

The principal orthographic views are the plan, the elevation, and the section.

Plan

A plan is the principal view of an object projected orthographically on a horizontal picture plane; also called top view. In architectural drawing, there are distinct types of plan views for representing various horizontal projections of a building or site.

Elevation

Elevation is a principal view of an object projected orthographically on a vertical picture plane. An elevation view may be a front, side, or rear view, depending on how we orient ourselves to the object or assess the relative significance of its faces. In architectural graphics, we label elevation views in relation to the compass directions or to a specific feature of a site.

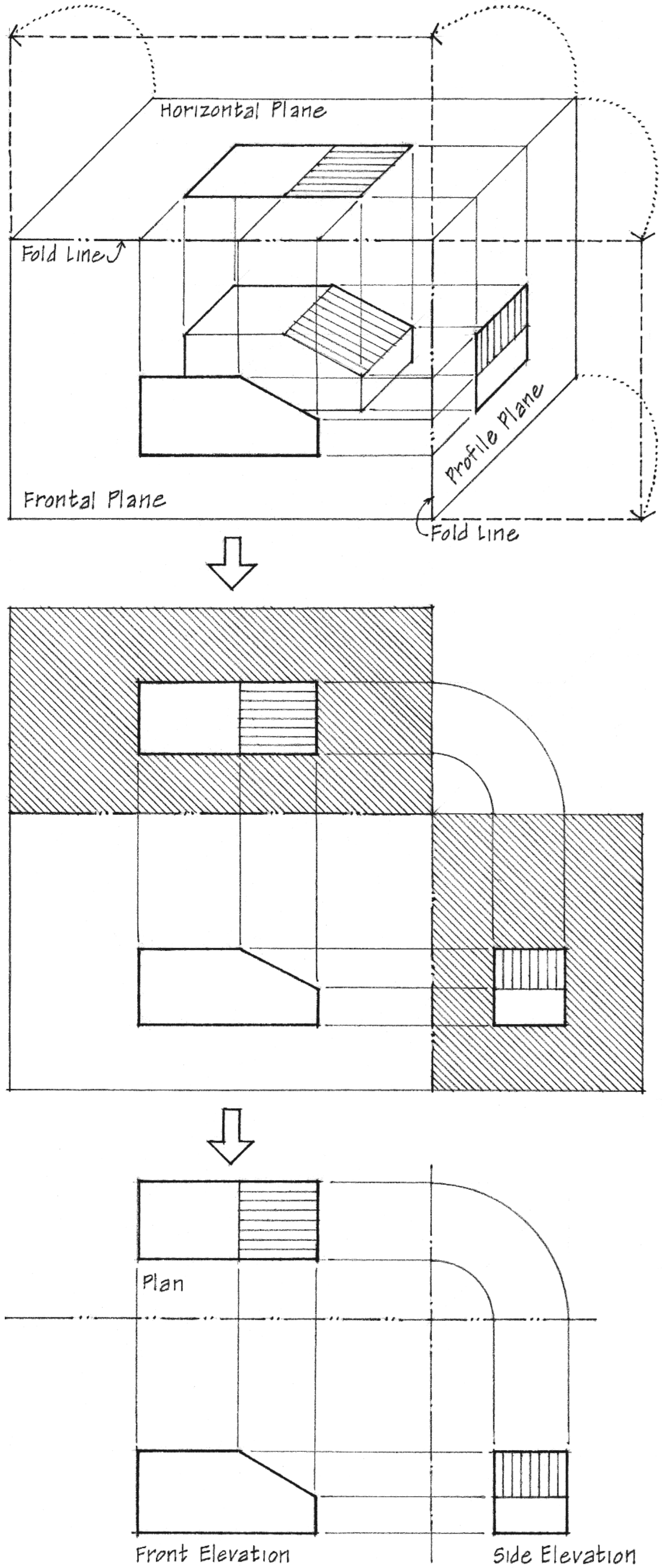
Section

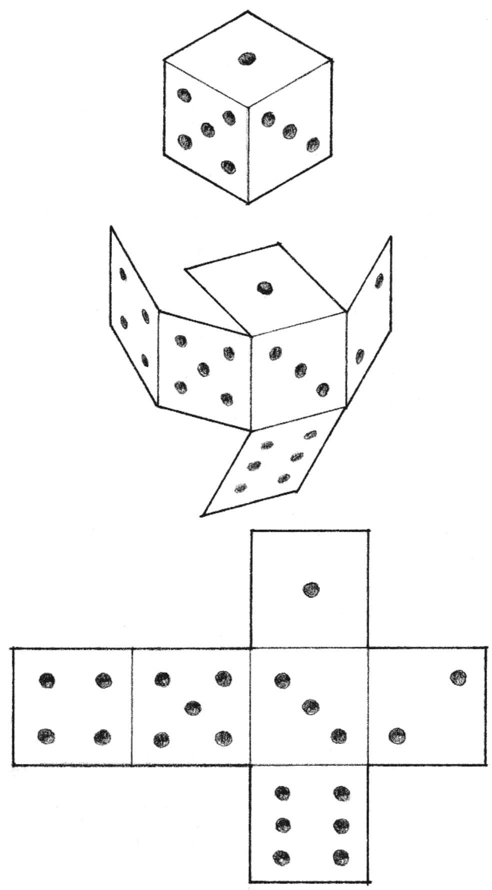
A section is an orthographic projection of an object as it would appear if cut through by an intersecting plane.

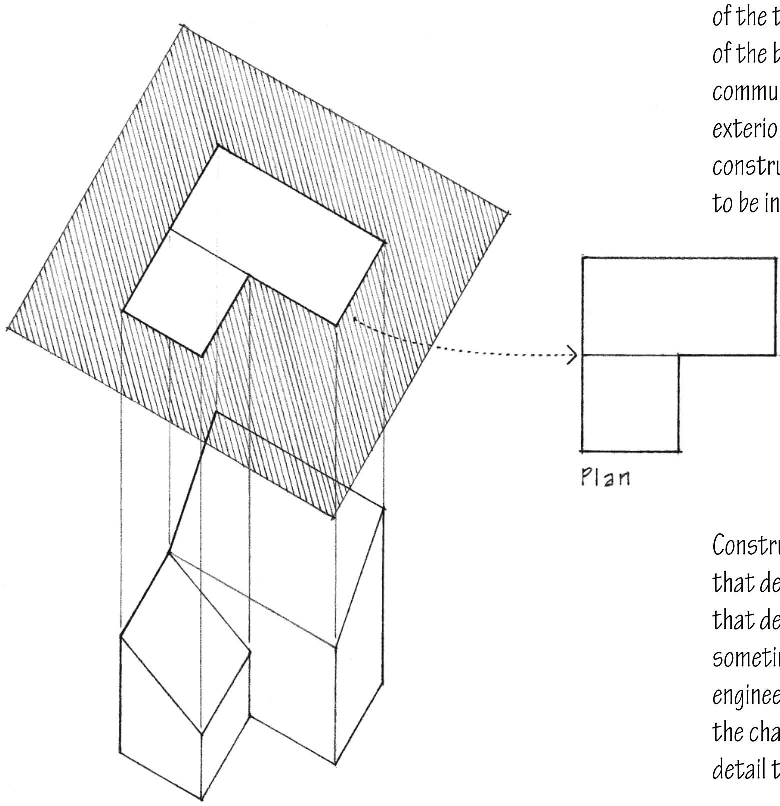
Arranging Views

To make it easier to read and interpret how a series of orthographic views describes a three-dimensional whole, we arrange the views in an orderly and logical fashion. The most common arrangement of plan and elevations results from unfolding the transparent picture-plane box in third-angle projection.

After each view is projected, we rotate the views about the fold lines into a single plane represented by the drawing surface. The top, or plan, view revolves upward to a position directly above and vertically aligned with the front or elevation view, while the side, or profile, view revolves to align horizontally with the front view. The result is a coherent set of related orthographic views separated by fold lines.

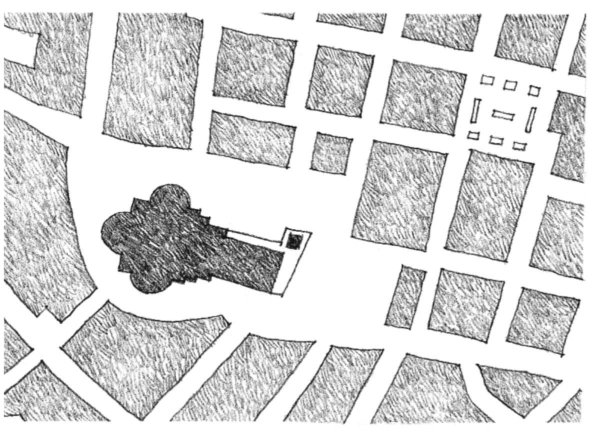


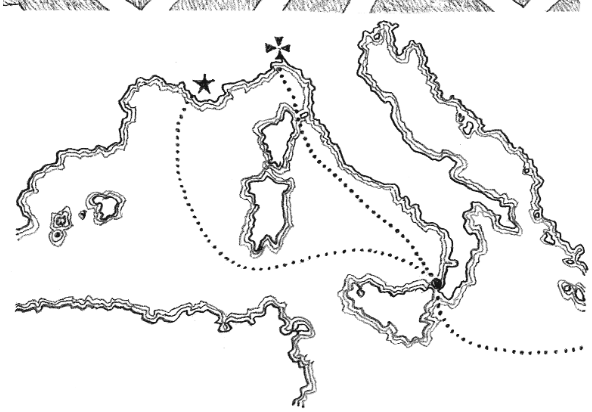




A standard set of construction documents will typically contain each of the types of drawing listed earlier. It will contain plans of every level of the building, roof plan, site plan, as many sections as required to communicate changes in spatial configuration, and elevations of every exterior surface, along with details that communicate assembly and construction techniques and schedules that list parts and components to be installed.

Construction documents will also contain drawings by MEP engineers that detail the installation of mechanical systems, structural engineers that detail the size and distribution of structural elements, and sometimes site information provided by a landscape architect or civil engineer. A greater number of drawings are necessary to communicate the characteristics of bigger or more complex projects with enough detail to build them.



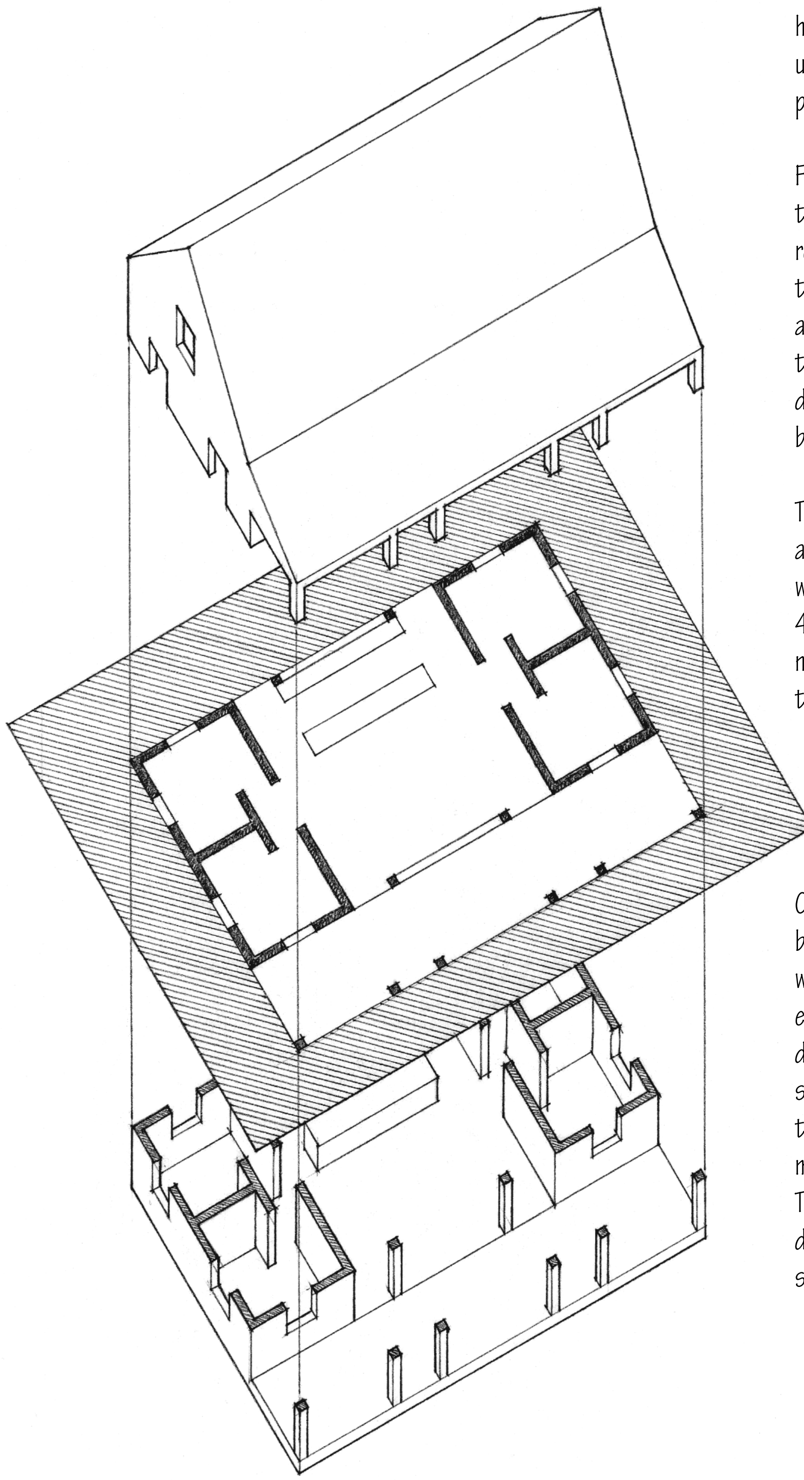


Plans

Plans are drawings of orthographic projections on a horizontal picture plane, usually drawn to scale. They represent a view looking down on an object, building, or scene from above. All planes parallel to the picture plane maintain their true-scale size, shape, and proportions.

Plans reduce the three-dimensional complexity of an object to its two-dimensional horizontal aspects. They depict width and length but not height. This emphasis on the horizontal is both the plan's limitation as well as its strength. It is ironic that while plan drawings are relatively easy to generate in comparison to the intricacies of linear perspectives, they are essentially abstract constructs, which can be difficult to read and understand. They depict an aerial viewpoint that we seldom experience except in the mind's eye.

In eliminating certain aspects from consideration, however, plans emphasize the horizontal arrangements and patterns of what we see or envision. These may be relationships of function, form, interior or exterior space, or of parts within a greater whole. In this way, plans match our mental map of the world and display a field of action for our thoughts and ideas.



Floor Plans

A floor plan represents a horizontal section of a building as it would appear if cut through by an intersecting plane. After a horizontal plane slices through the construction, we remove the upper part. The floor plan is an orthographic projection of the portion that remains.

Floor plans open up the interior of a building to reveal a view that would otherwise not be possible. They unveil horizontal relationships and patterns not easily detected when walking through a building. On a horizontal picture plane, floor plans are able to disclose the configuration of walls and columns, the shape and dimensions of spaces, the layout of window and door openings, and the connections between spaces as well as between the interior and exterior.

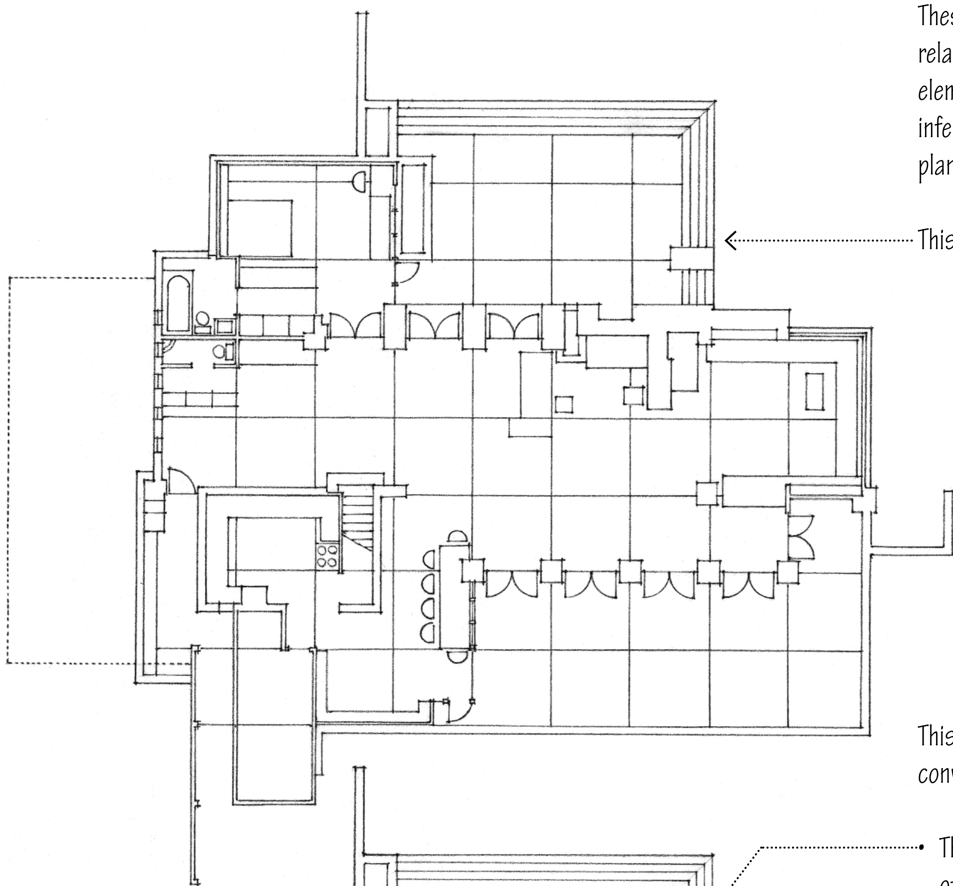
The horizontal plane of a plan slices through walls, columns, and other vertical elements of a building, as well as through all window and door openings. The plane of the cut is usually about 4 feet above the floor, but its height can vary according to the nature of the building design. Below the plane of the cut, we see the floor, counters, tabletops, and similar horizontal surfaces.

Critical to reading a floor plan is the ability to distinguish between solid matter and spatial void and to discern precisely where mass meets space. It is, therefore, important to emphasize in a graphic way what is cut in a floor plan, and to differentiate the cut material from what we can see through space below the plane of the cut. In order to convey a sense of the vertical dimension and the existence of a spatial volume, we must use a hierarchy of line weights or a range of tonal values. The technique we use depends on the scale of the floor plan, the drawing medium, and the required degree of contrast between solid matter and spatial void.

The Plan Cut

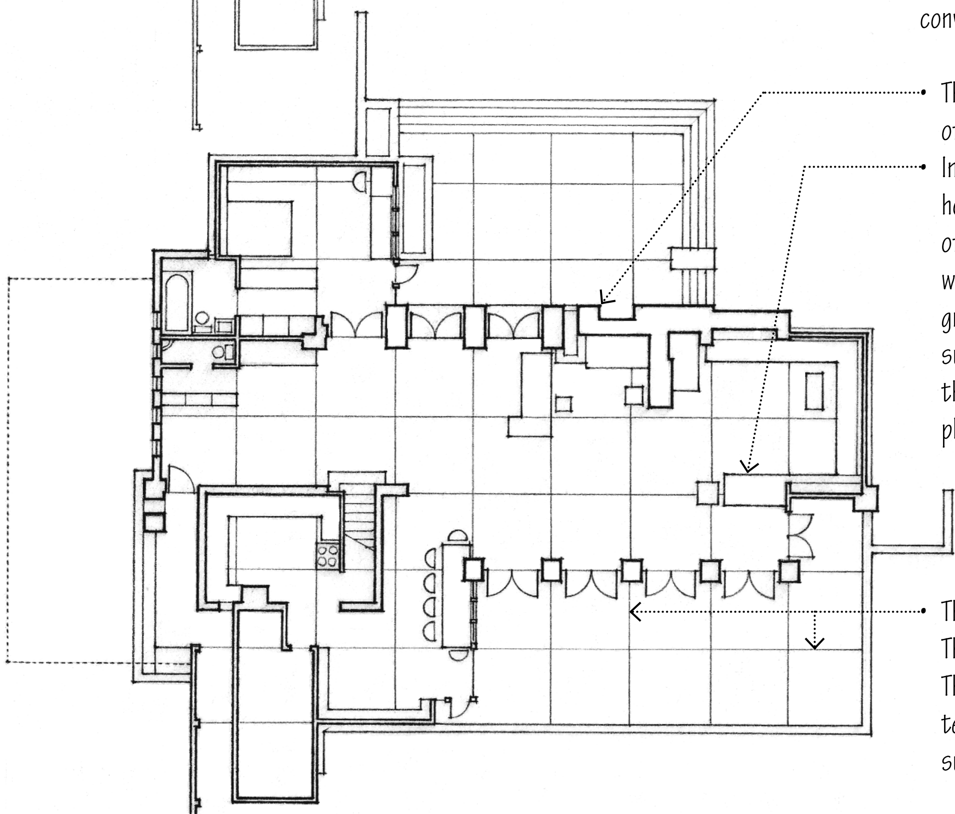
These drawings illustrate how we can use the relative weights of lines to emphasize the vertical elements that are cut in a floor plan as well as to infer the relative depth of elements beyond the plane of the cut.

This is a floor plan drawn with a single line weight.



This drawing uses a hierarchy of line weights to convey depth.

- The heaviest line weight profiles the plan shapes of cut materials, such as walls and columns.
- Intermediate line weights delineate edges of horizontal surfaces that lie below the plane of the plan cut but above the floor, such as windowsills, countertops, and railings. The greater the vertical drop from one horizontal surface to the next, the heavier the line weight; the further away a horizontal surface is from the plane of the plan cut, the lighter the line weight.
- The lightest line weights represent surface lines. These lines do not signify any change in form. They simply represent the visual pattern or texture of the floor plane and other horizontal surfaces.



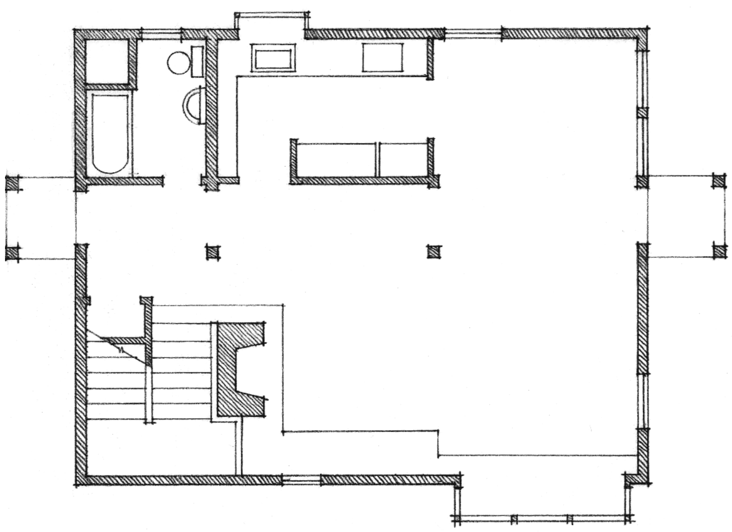
Schwartz House, Two Rivers, Wisconsin, 1939, Frank Lloyd Wright

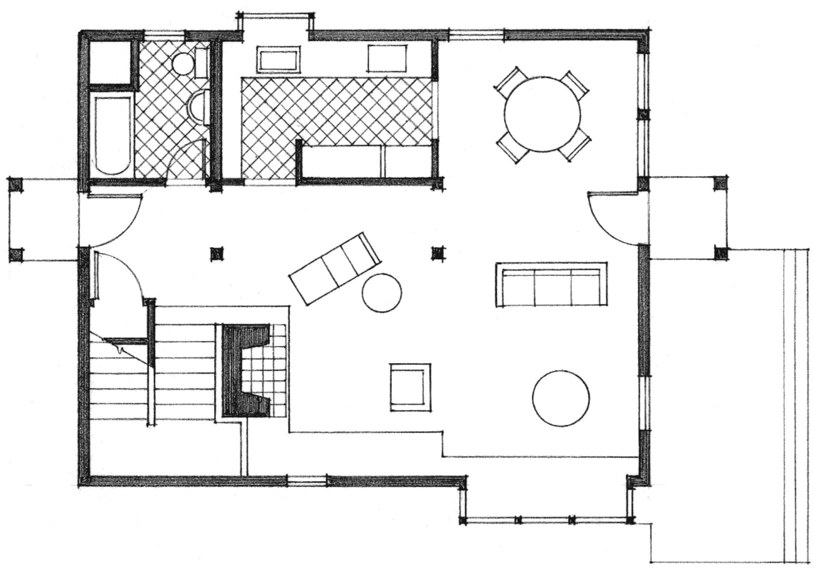
Poché

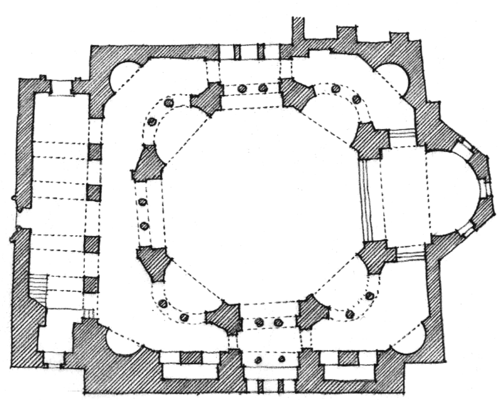
In a line-and-tone or pure tone drawing, we emphasize the shape of cut elements with a tonal value that contrasts with the spatial field of the floor plan. We refer to this darkening of cut walls, columns, and other solid matter as poché.

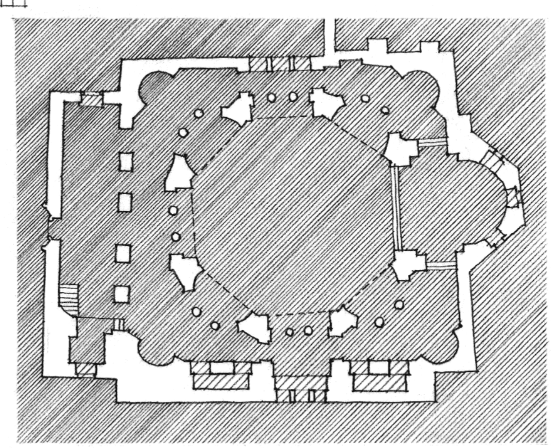
It is typical to blacken the cut elements in small-scale plans in order to give them prominence. If only a moderate degree of contrast with the drawing field is desired, use a middle-gray value to illuminate the shape of the cut elements. This is especially important in large-scale plans when large areas of black can carry too much visual weight or create too stark a contrast. However, if plan elements such as flooring patterns and furniture give the field of the drawing a tonal value, a dark gray or black tone may be necessary to produce the desired degree of contrast between solid matter and spatial void.

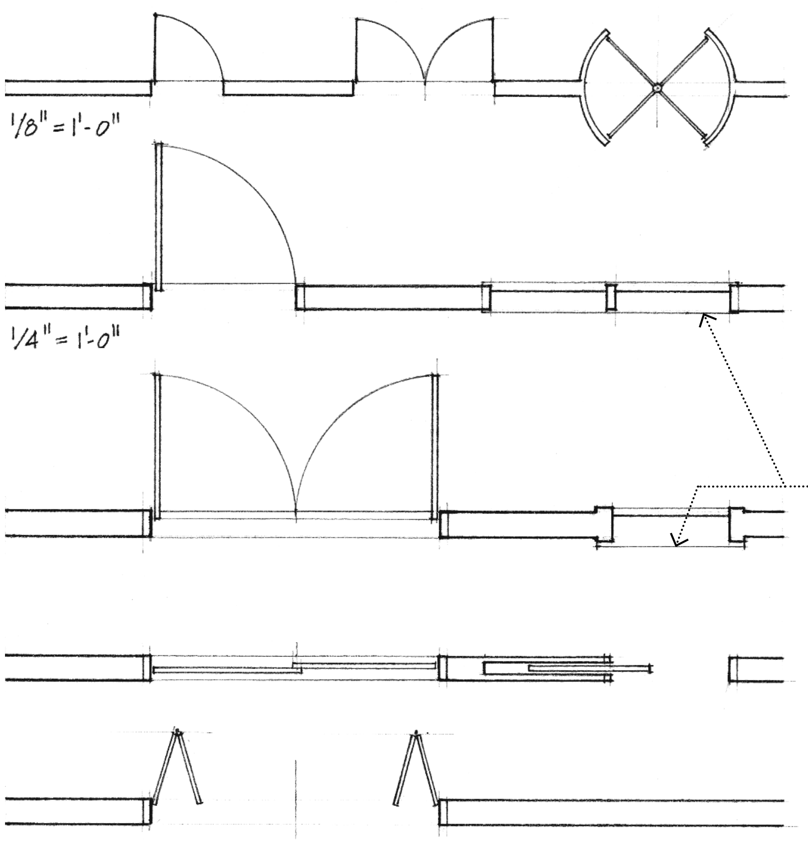
Poché establishes a figure-ground relationship between solid and void—between container and contained. We tend to read the cut elements of a floor plan as figures and the bounded space as background. To focus on the shape of space as figure, we can reverse the normal pattern of dark marks drawn on a light surface and instead produce light marks on a dark surface.







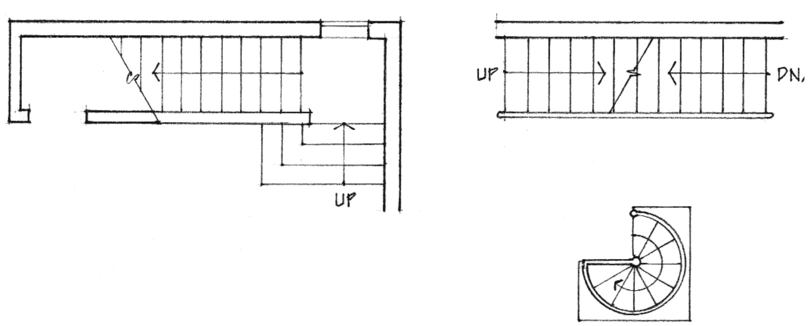




Doors and Windows

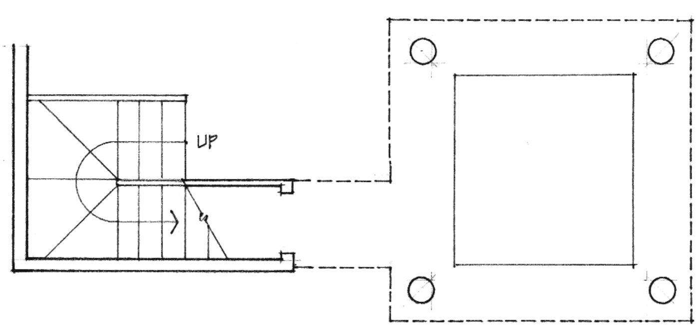
We are not able to show the appearance of doors in a plan view. For this information, we must rely on elevations. What a floor plan does show, however, are the location and width of door openings, and to a limited degree, the door jambs and type of door operation—whether a door swings, slides, or folds open. For example, we typically draw a swinging door perpendicular to the plane of the wall and denote the door swing with a lightly drawn quarter circle.

Neither can we show the appearance of windows in a plan view. A floor plan does disclose the location and width of window openings, and to a limited degree the presence of window jambs and mullions. However, the plan view should include the windowsill below the plane of the plan cut, which passes through the glass panes and frame of a window.



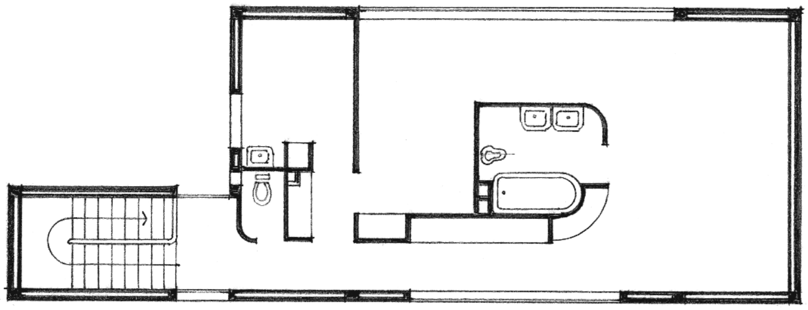
Stairs

Plan views are able to show the run of a stairway—its horizontal treads and landings—but not the height of the vertical risers. The path of travel terminates where the stairway passes through the plane of the plan cut. We use a diagonal line to indicate this cut in order to more clearly distinguish it from the parallel lines of the stair treads. An arrow specifies the direction up or down from the level of the floor plan. Above the plan cut, we can use a dashed line to complete the opening through which a stairway rises.

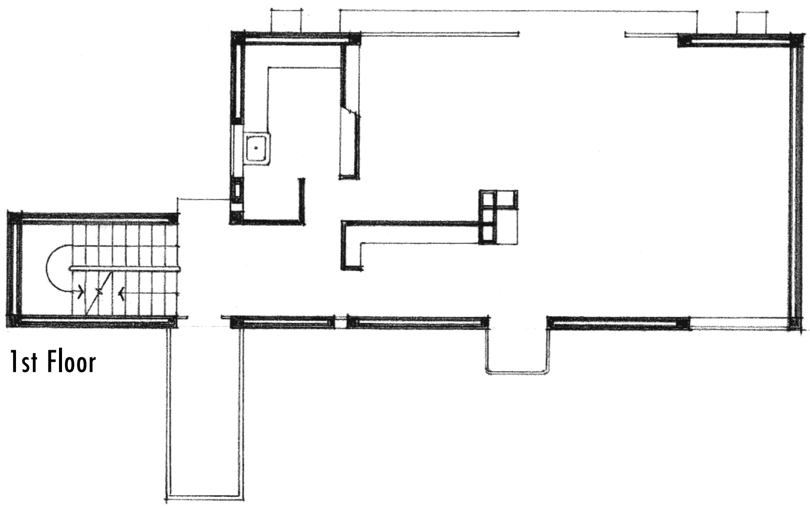


Elements above or below the Plan Cut

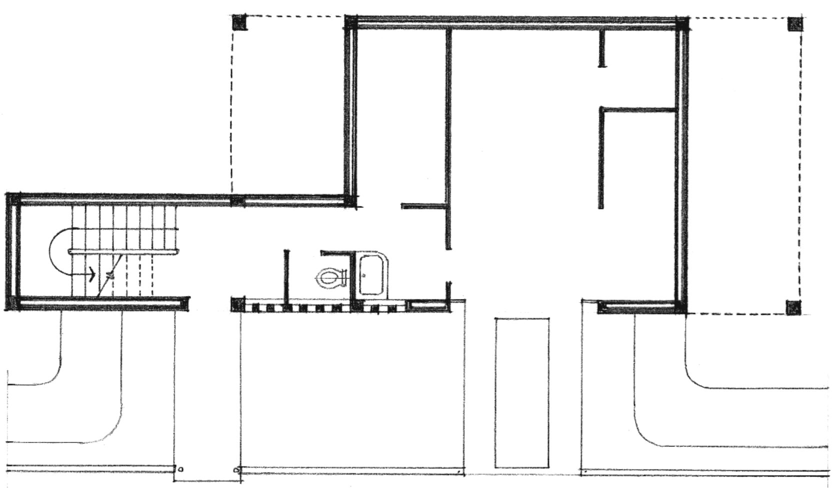
Dashed lines indicate major architectural features that occur above the plane of the plan cut, such as lofts, lowered ceilings, exposed beams, skylights, and roof overhangs. Dashed lines may also disclose the hidden lines of features concealed from view by other opaque elements. The common convention is to use longer dashes to signify elements that are removed or above the plane of the plan cut, and shorter dashes or dots for hidden elements below the plan cut.



2nd Floor



1st Floor



Ground Floor

Villa at Vaucresson, France, 1922, Le Corbusier

Orientation

To orient the viewer to the surrounding environment, we accompany a floor plan with a north arrow. The normal convention is to orient floor plans with north facing up or upward on the drawing sheet.

If a major axis of the building is less than 45° east or west of north, we can use an assumed north to avoid wordy titles for the building elevations, as "north-northeast elevation," or "south-southwest elevation."

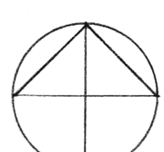
Whenever possible, orient the floor plan of a room with its entrance at the bottom of the drawing so that we can imagine entering the room in an upward direction. When keying a room plan to a floor plan of a building, however, orienting both plans in the same manner takes precedence.

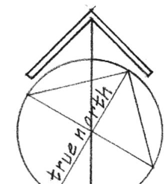
Arrangement

In laying out the floors plans of a multistory building, align the plans either vertically, directly above one another, or horizontally side by side. Vertical arrangements should begin with the lowest level at the bottom and rise to the highest level at the top. Horizontal arrangements should generally proceed from the lowest floor to the upper levels, reading from left to right.

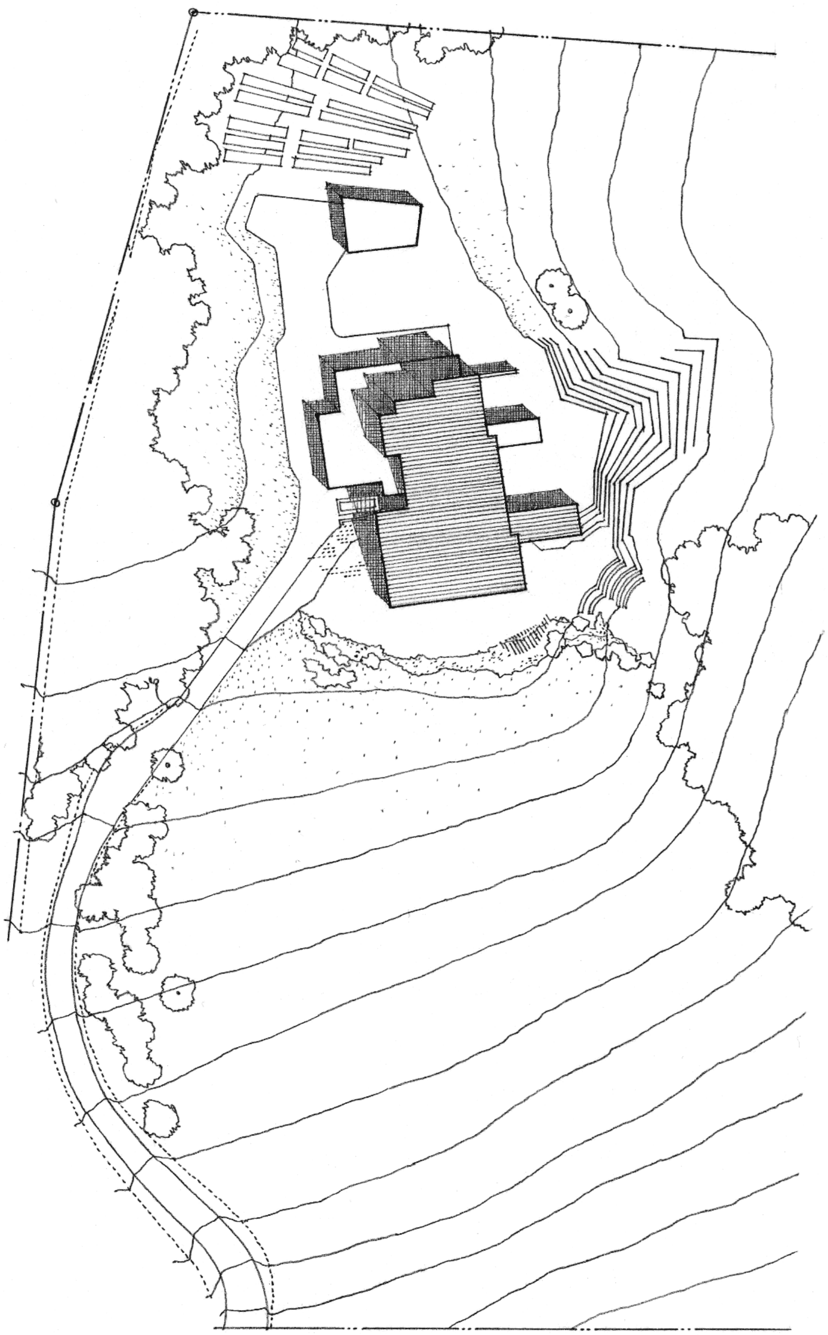
Aligning a series of floor plans in these two ways makes it easier to read and understand the vertical relationships between elements that occur or rise through two or more floor levels of a building. To strengthen this reading, relate the plans of linear buildings along their long side whenever possible.

The first or ground floor plan often extends out to include adjacent outdoor spaces and features, as courtyards, landscaping, and garden structures.





assumed north



Site Plans

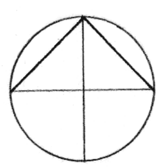
A site plan describes the location and orientation of a building or building complex on a plot of land and in relation to its context. Whether this environment is urban or rural, the site plan should describe the following:

- The legally recorded boundaries of the site, indicated by a broken line consisting of relatively long segments separated by two short dashes or dots
- The physical topography of the terrain with contour lines
- Natural site features, such as trees, landscaping, and watercourses
- Existing or proposed site constructions, such as walks, courts, and roadways;
- Architectural structures in the immediate setting that impact the proposed building

In addition, a site plan may include:

- Legal constraints, such as zoning setbacks and right-of-ways
- Existing or proposed site utilities
- Pedestrian and vehicular entry points and paths
- Significant environmental forces and features

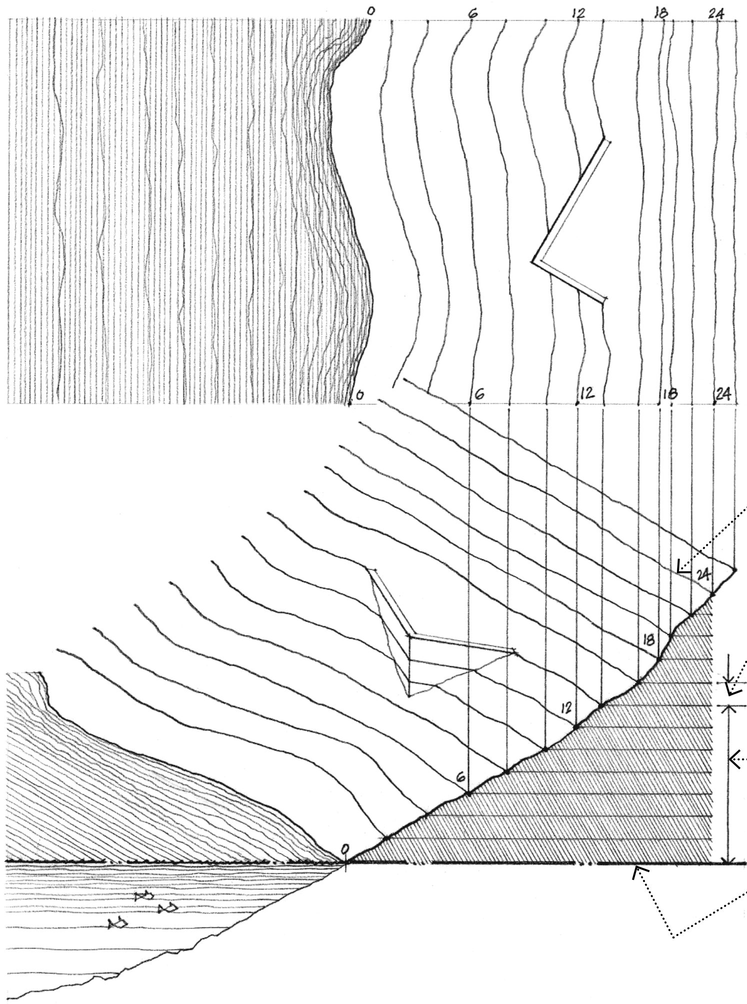
Site plan, Carré House, Bazoches-sur-Guyonne, France, 1952–1956, Alvar Aalto



Site Contours

The response of a building design to its context includes consideration of the physical characteristics of its site, especially the surface configuration of the terrain. A series of site sections can effectively represent this information. On a site plan, however, it is difficult to describe the vertical aspect of an undulating ground surface. Contour lines are the graphic convention we use to convey this information.

One way to visualize contour lines is to imagine that horizontal slices cut through the landform at regular intervals, the profile of each cut being represented by a contour line. The trajectory of each contour line indicates the shape of the land formation at that elevation. Contour lines are always continuous and never cross one another. They coincide in a plan view only when they cut across a vertical surface.



Contour Line
A contour line is an imaginary line joining points of equal elevation on a ground surface.

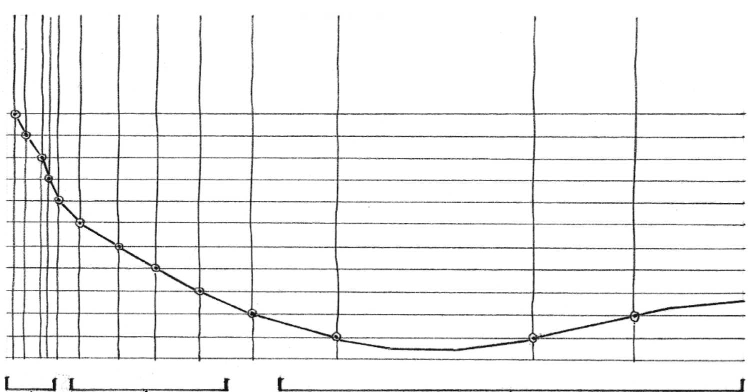
Contour Interval
The contour interval is the difference in elevation represented by any two adjacent contour lines on a topographic map or site plan.

Elevation
Elevation is the vertical distance of a point above or below a datum.

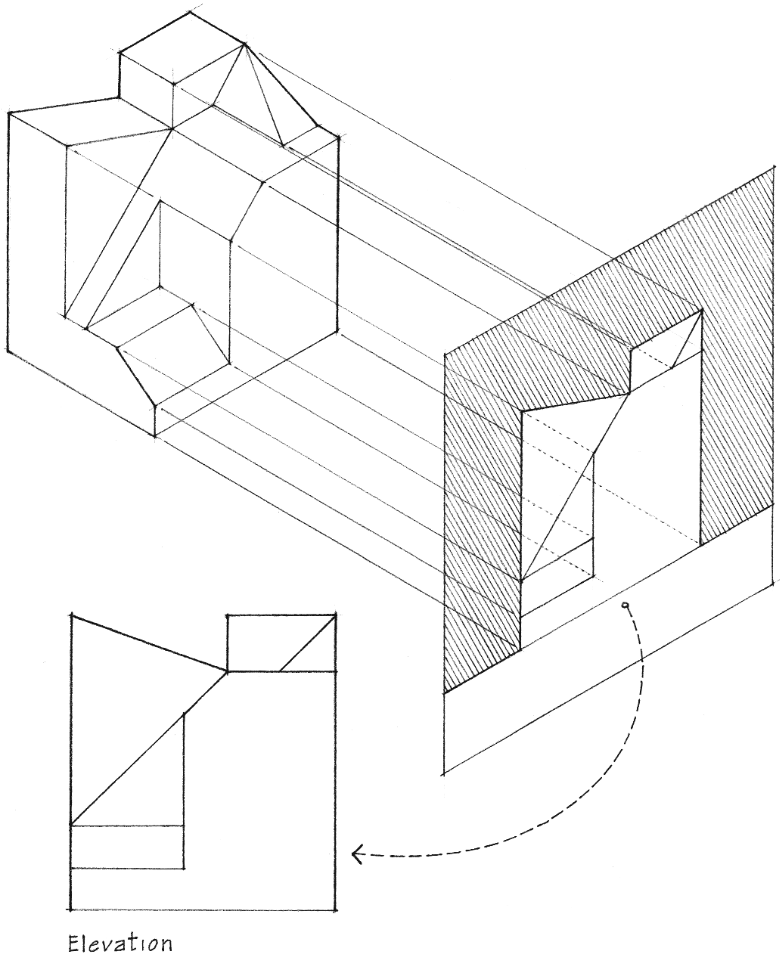
Datum
A datum is any level surface, line, or point used as a reference from which elevations are measured.

The contour interval is determined by the scale of a drawing, the size of the site, and the nature of the topography. The larger the area and the steeper the slopes, the greater the interval between contours. For large or steeply sloping sites, 10-ft, 25-ft, or 50-ft contour intervals may be used. For small sites with relatively gradual slopes, 5-ft, 2-ft, or 1-ft contour lines may be used.

The horizontal distances between contour lines in a site plan are a function of the slope of the ground surface. We can discern the topographical nature of a site by reading this horizontal spacing.



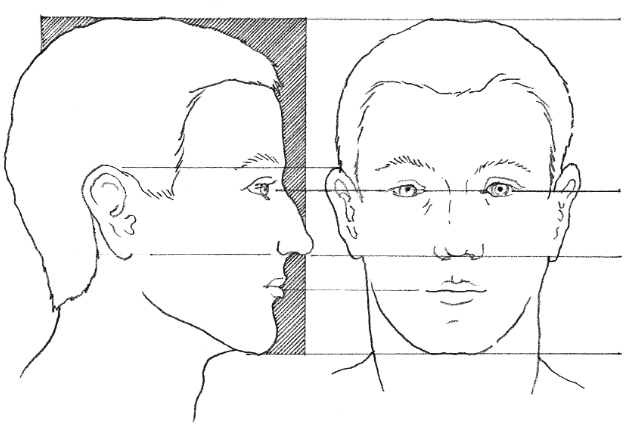
- Contours spaced far apart indicate a relatively flat or gently sloping surface.
- Equally spaced contours indicate a constant slope.
- Closely spaced contours indicate a relatively steep rise in elevation.

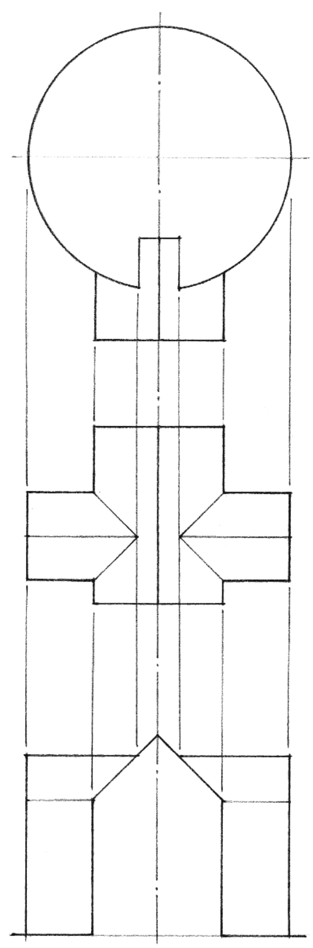


Elevations

An elevation is an orthographic projection of an object or construction on a vertical picture plane parallel to one of its sides. As with other orthographic projections, all planes parallel to the picture plane maintain their true-scale size, shape, and proportions. Conversely, any plane that is curved or oblique to the picture plane will be foreshortened in the orthographic view.

Elevations reduce the three-dimensional complexity of an object to two dimensions—height and either width or length. Unlike a plan, an elevation mimics our upright stance and offers a horizontal viewpoint. Unlike a section, it does not involve a cut through the object being depicted. Instead, the elevation offers an exterior view that closely resembles the natural appearance of the object. Even though elevation views of vertical surfaces are closer to perceptual reality than either plans or section views, they cannot represent the diminishing size of planes as they recede from the spectator. When we draw objects and surfaces in elevation, we must rely on graphic cues to convey depth, curvature, or obliqueness.





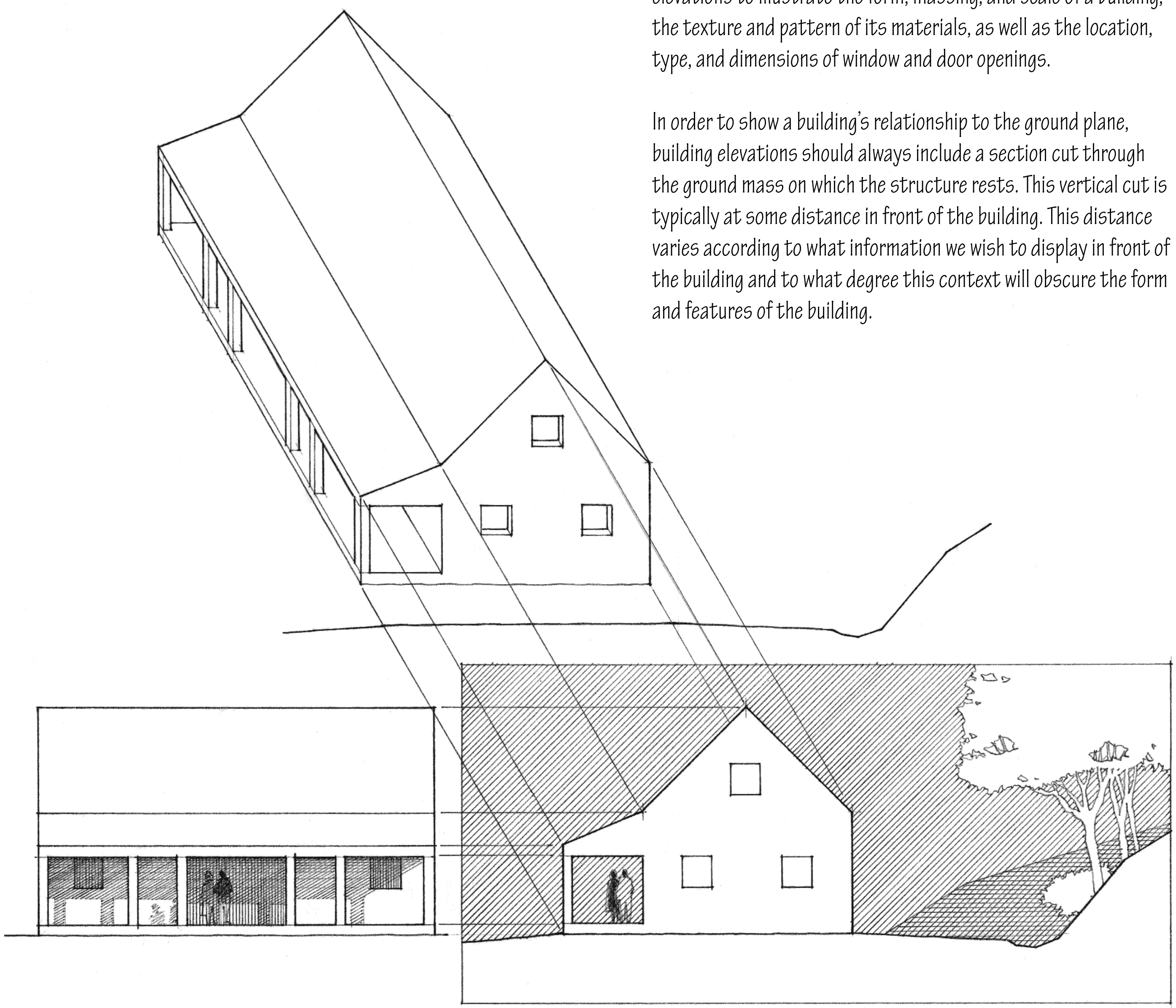
The two different plan views can generate the same elevation.

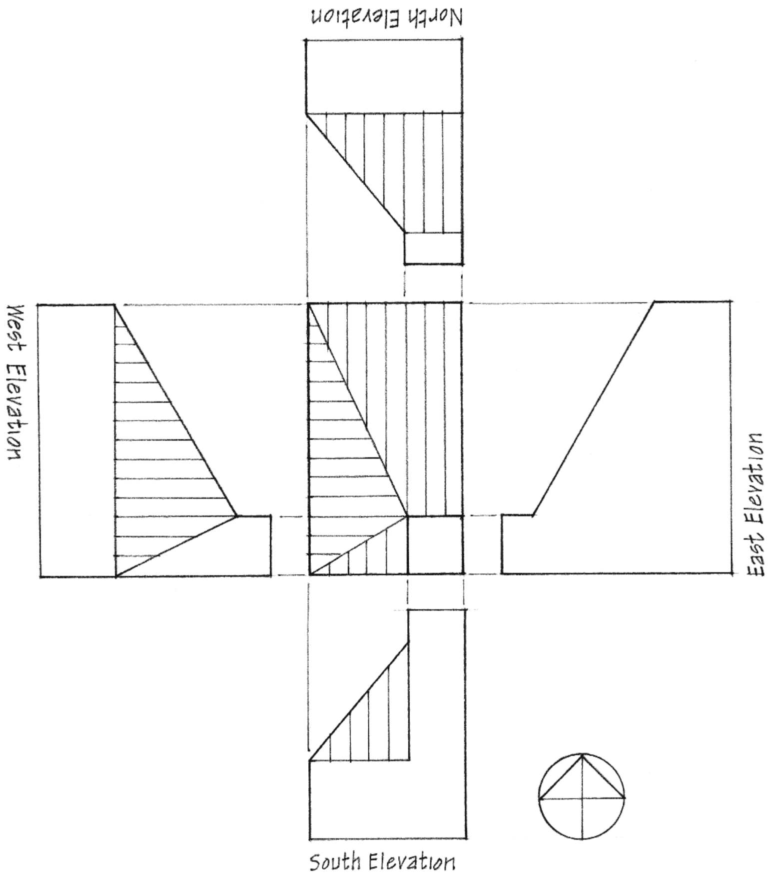
Building Elevations

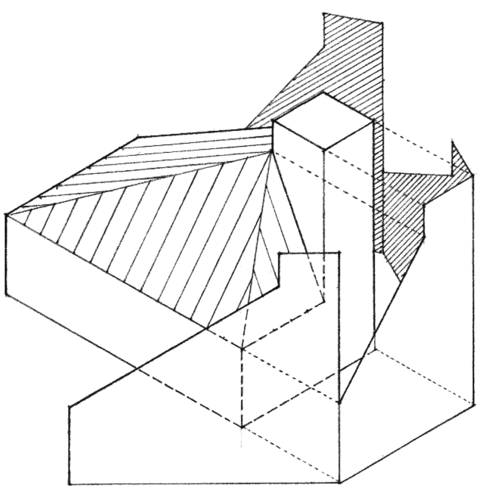
A building elevation is a horizontal view of the image of a building projected orthographically onto a vertical picture plane. We normally orient the picture plane to be parallel to one of the principal faces of the building.

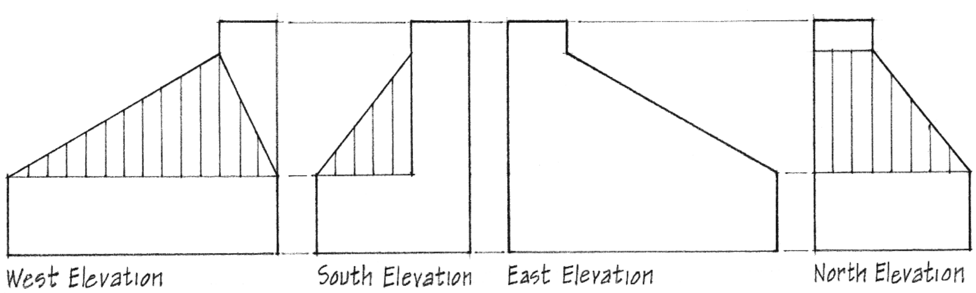
Building elevations convey the external appearance of a building, compressed onto a single plane of projection. They, therefore, emphasize the exterior vertical surfaces of a building parallel to the picture plane and define its silhouette in space. We use building elevations to illustrate the form, massing, and scale of a building, the texture and pattern of its materials, as well as the location, type, and dimensions of window and door openings.

In order to show a building's relationship to the ground plane, building elevations should always include a section cut through the ground mass on which the structure rests. This vertical cut is typically at some distance in front of the building. This distance varies according to what information we wish to display in front of the building and to what degree this context will obscure the form and features of the building.









Arrangement

As we move around a building, we see a series of related elevations that changes as our position in space changes. We can logically relate these views to each other by unfolding the vertical picture planes on which they are projected. They can form a horizontal sequence of drawings, or be related in a single, composite drawing around a common plan view.

While an elevation drawing can show the context of objects and the relationships between a number of forms in space, they do not reveal any information about their interiors. We can combine elevations and sections, however, when drawing symmetrical forms and constructions.

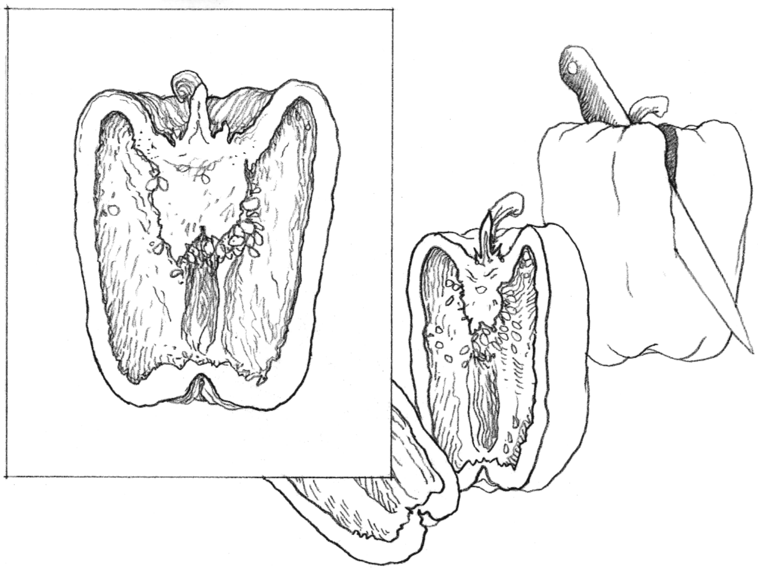
Orientation

To orient the viewer, we label each elevation drawing according to its relationship to an assumed front face, the compass direction it faces, or the context from which the elevation is seen. An elevation view may be a front view if projected on a frontal plane of projection, and a side view if projected on the profile plane, depending on how we orient ourselves to the object or assess the relative significance of its faces.

In architectural graphics, however, the orientation of a building to the compass points is an important consideration when studying and communicating the effect of solar radiation and other climatic factors on the design. Therefore, we most often name a building elevation after the direction the elevation faces: for example, a north elevation is the elevation of the façade that faces north. If the face is oriented less than 45° off the major compass points, an assumed north may be used to avoid wordy drawing titles.

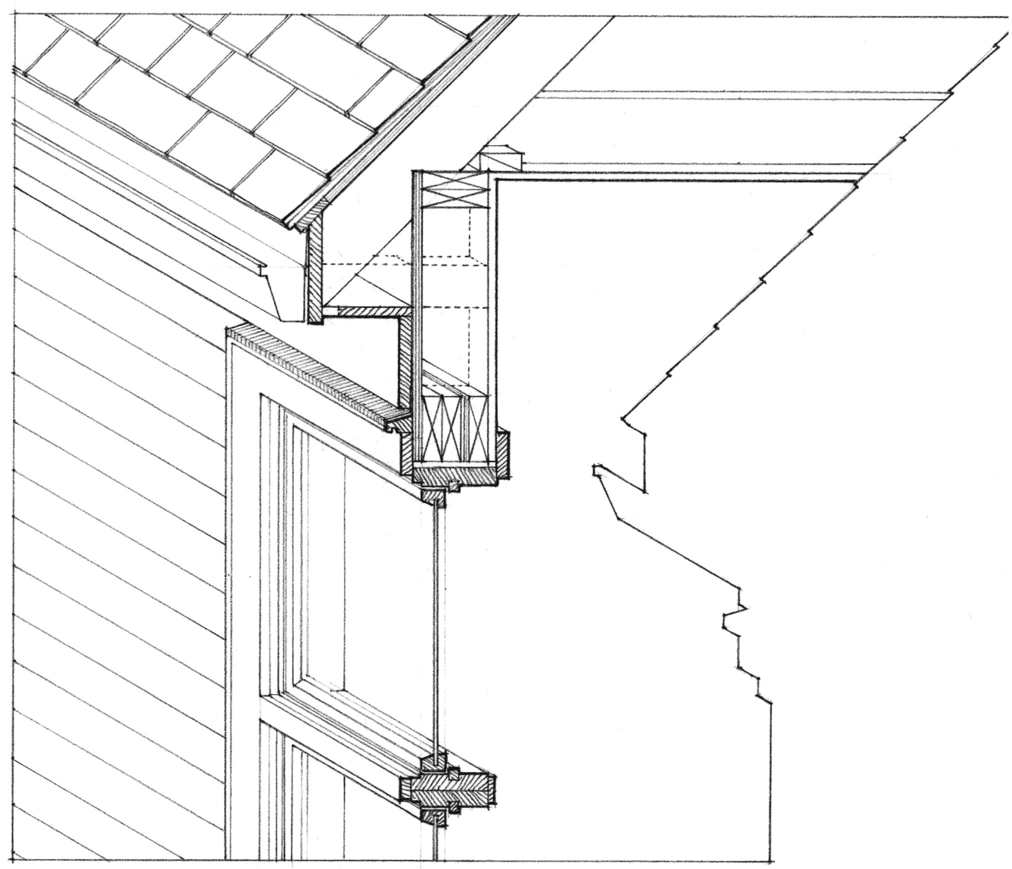
When a building addresses a specific or significant feature of a site, we can name a building elevation after that feature: for example, a street elevation is the elevation of the façade that faces a street.

Section Drawings



A section is an orthographic projection of an object as it would appear if cut through by an intersecting plane. It opens up the object to reveal its internal material, composition, or assembly. In theory, the plane of the section cut may have any orientation. However, in order to distinguish a section drawing from a floor plan—the other type of drawing that involves a slice—we usually assume the plane of the cut for a section is vertical and the view is horizontal. As with other orthographic projections, all planes parallel to the picture plane maintain their true-scale size, shape, and proportions.

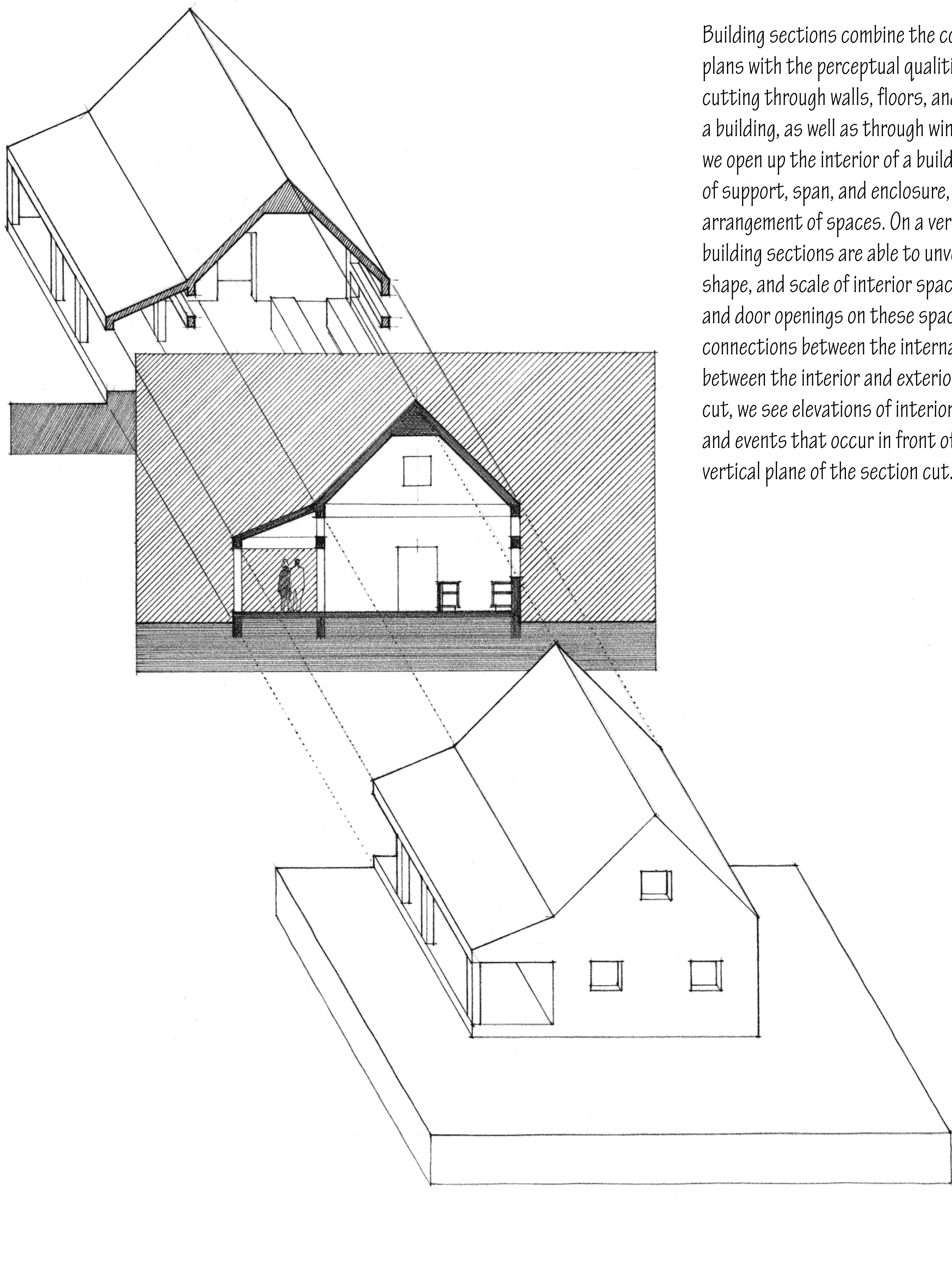
Sections reduce the three-dimensional complexity of an object to two dimensions—height and either width or length. We often use section drawings to design and communicate the details of a building's construction as well as the assembly of furniture and cabinetry. In architectural graphics, however, the building section is the premier drawing for studying and revealing the vital solid-void relationship between the floors, walls, and roof structure of a building, and the vertical dimensions and relationships of the contained spaces.



Building Sections

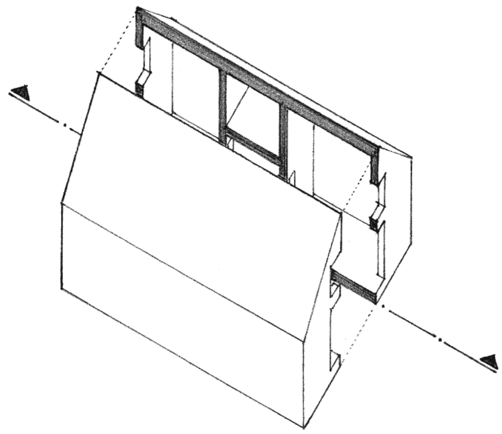
A building section represents a vertical section of a building. After a vertical plane slices through the construction, we remove one of the parts. The building section is an orthographic projection of the portion that remains, cast onto a vertical picture plane parallel to the plane of the incision.

Building sections combine the conceptual qualities of plans with the perceptual qualities of elevations. In cutting through walls, floors, and the roof structure of a building, as well as through window and door openings, we open up the interior of a building to reveal conditions of support, span, and enclosure, as well as the vertical arrangement of spaces. On a vertical picture plane, building sections are able to unveil the vertical dimension, shape, and scale of interior spaces, the impact of window and door openings on these spaces, and the vertical connections between the internal spaces, as well as between the interior and exterior. Beyond the plane of the cut, we see elevations of interior walls as well as objects and events that occur in front of them but behind the vertical plane of the section cut.



Locating the Section Cut

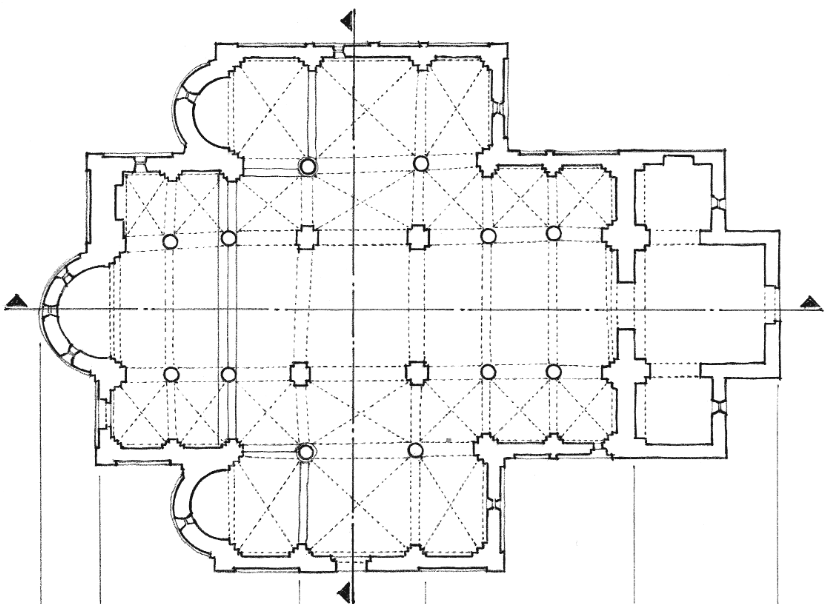
For buildings having a symmetrical plan, the logical location for a section cut is along the axis of symmetry. In all other cases, a building section should cut through the most significant spaces and look in a direction that reveals the principal features of the spaces. To avoid confusion, we usually make the incision along a continuous vertical plane parallel to a major set of walls. Use offsets only when absolutely necessary.

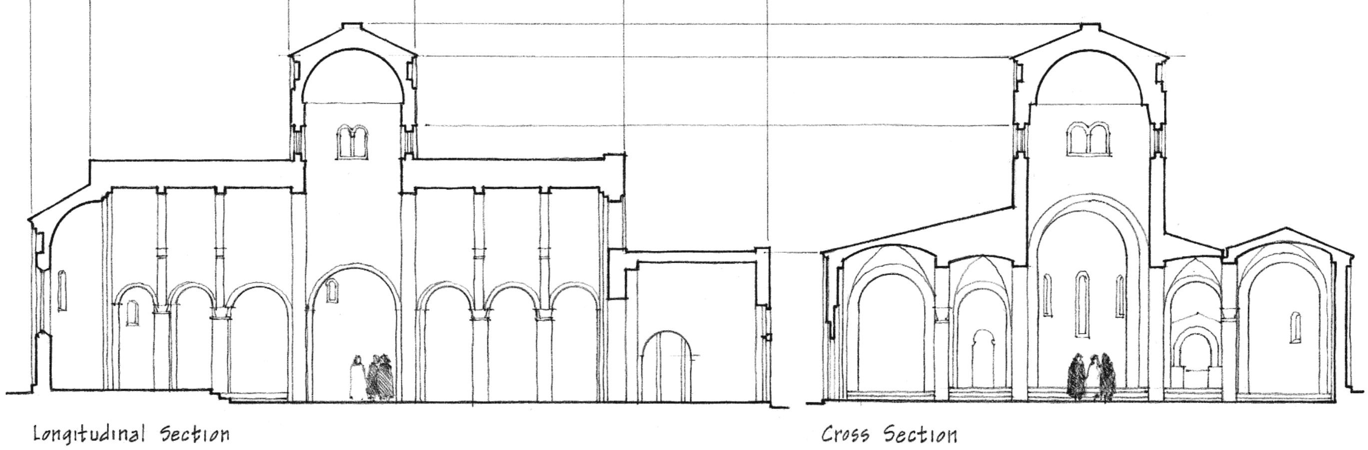


More specifically, a building section should cut through key architectural features, such as important window and door openings, skylighting, major changes in level, and special conditions of vertical circulation. Never slice vertically through columns or posts, as the cuts would read as continuous wall planes in the section drawing.

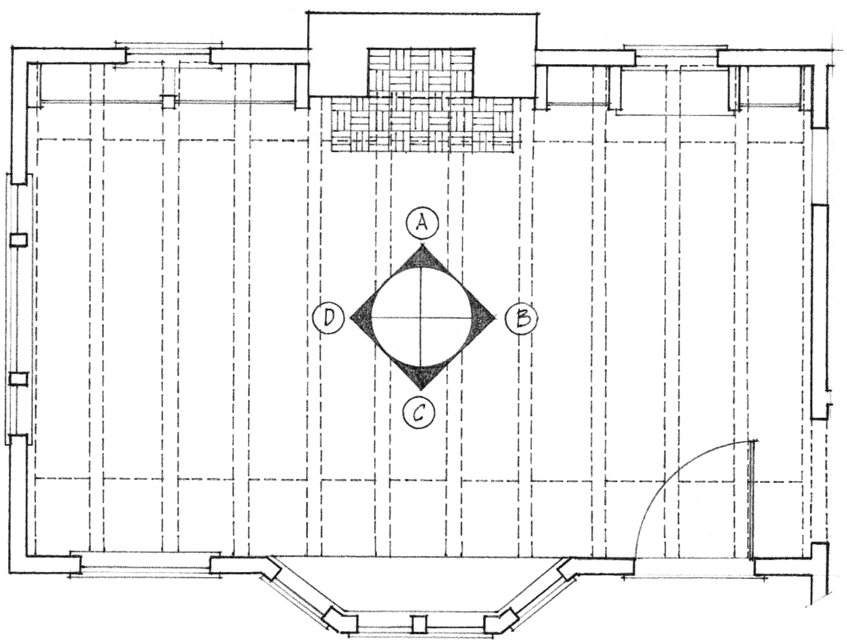
Cross sections refer to sections cut across the short dimension of things, while longitudinal sections cut through the long dimension. In either case, it is necessary to indicate precisely where a section cut is made and the direction of the view.

We do this by annotating the accompanying floor plan. The conventional symbol is a broken line of long segments separated by short dashes or dots. It is not necessary to draw this section line across an entire floor plan, except when the cut includes a number of offsets. More commonly, we indicate the location of a section cut with two short lines where the cutting plane emerges from the edges of the floor plan. An arrow at the end of each line points in the direction of view.





Abbey Church of S. Maria, Portonovo, Italy, twelfth century

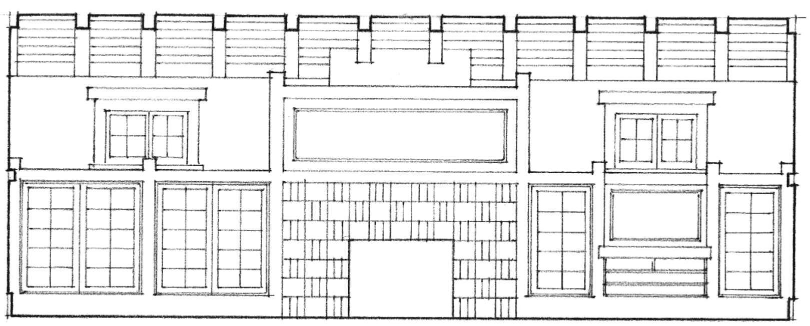


Interior Elevations

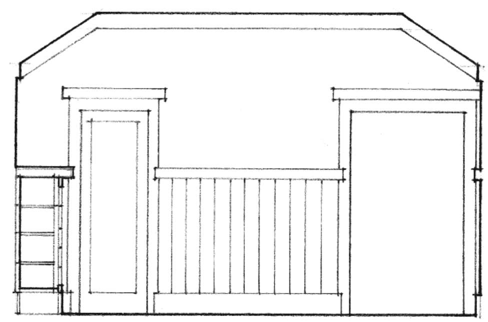
Interior elevations are orthographic projections of significant interior walls of a building. While normally included in the drawing of building sections, they may stand alone to illustrate the interior features of a room, such as doorways and built-in furnishings and fixtures. In this case, instead of profiling the section cut, we emphasize instead the boundary line of the interior wall surfaces.

Orientation

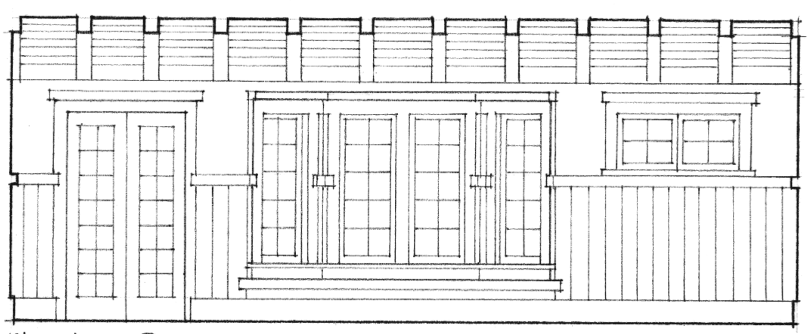
To orient the viewer, we label each interior elevation according to the compass direction toward which we look in viewing the wall. An alternative method is to key each interior elevation to a compass on the floor plan of the room.



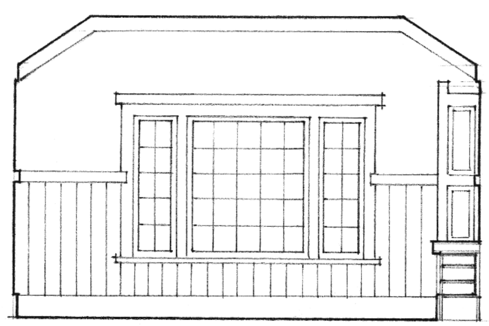
Elevation (A)



Elevation (B)



Elevation (C)

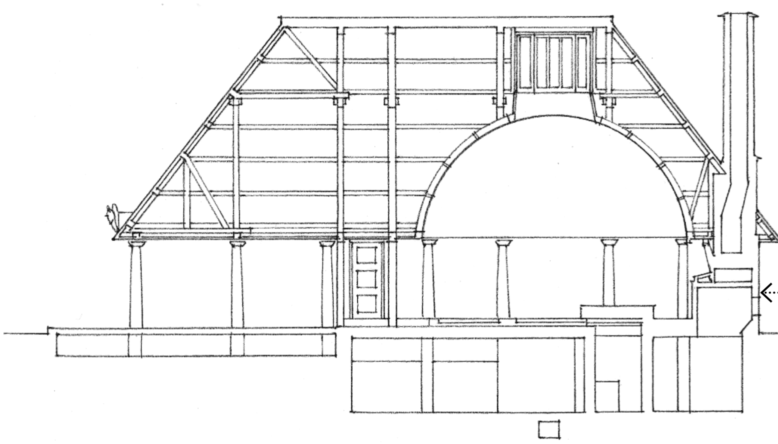


Elevation (D)

The Section Cut

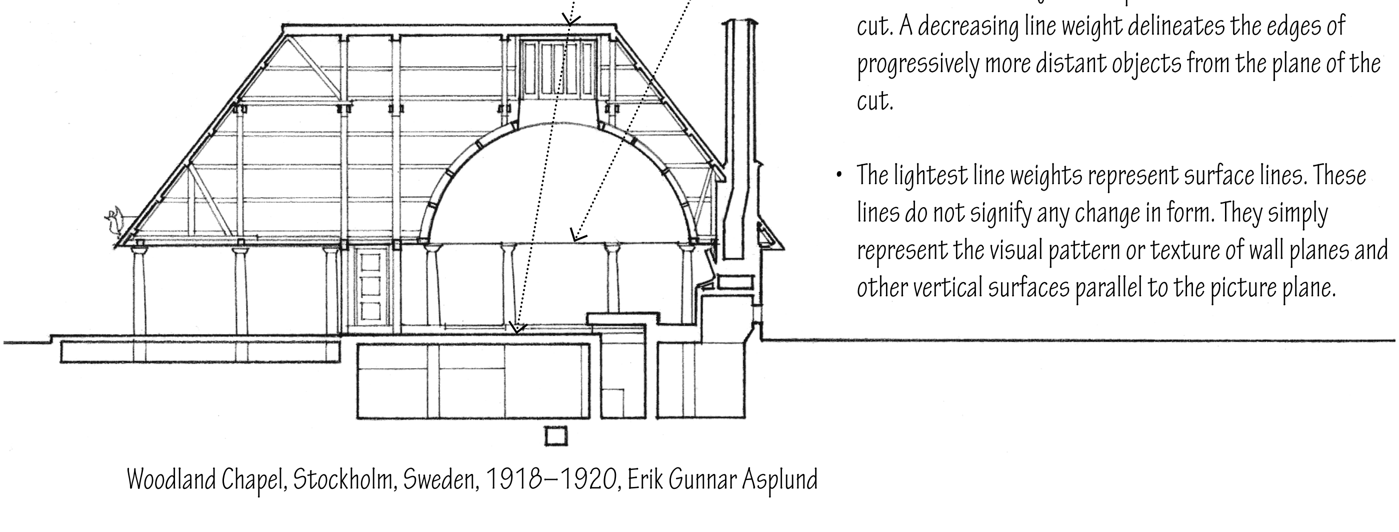
As with floor plans, it is critical to distinguish between solid matter and spatial void and to discern precisely where mass meets space in a building section. In order to convey a sense of depth and the existence of spatial volumes, we must utilize a hierarchy of line weights or a range of tonal values. The technique we use depends on the scale of the building section, the drawing medium, and the required degree of contrast between solid matter and spatial void.

These drawings illustrate how we can emphasize the solid material that is cut in a line drawing of a building section.

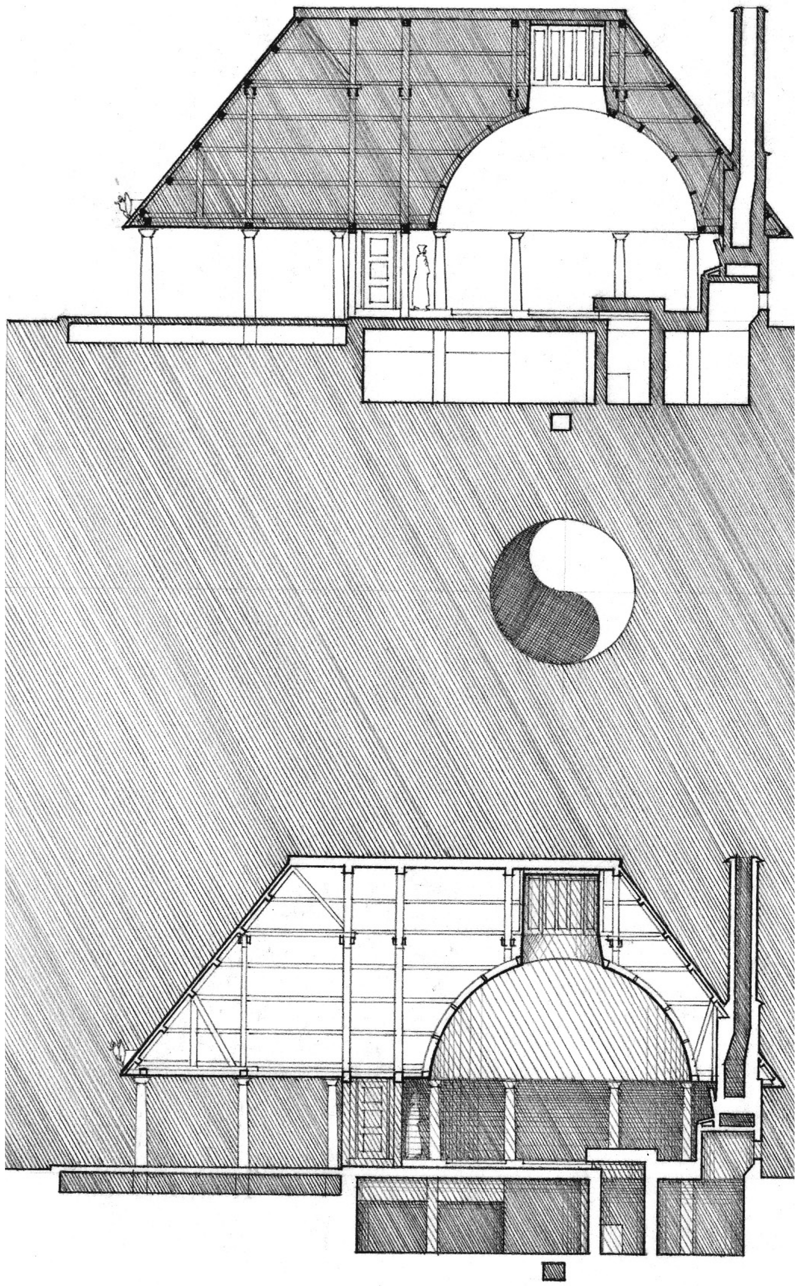


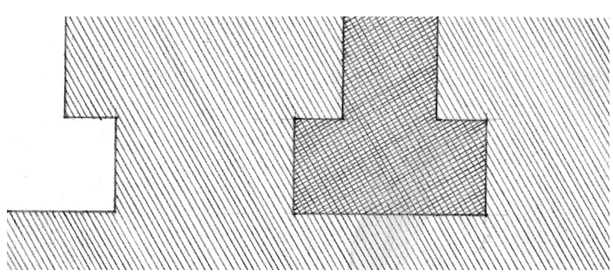
- This is a building section drawn with a single line weight.

- This drawing uses a hierarchy of line weights to convey depth.
- The heaviest line weight profiles the shape of cut materials that are closest to the viewer.
- Intermediate line weights delineate edges of vertical surfaces that lie beyond the plane of the section cut. A decreasing line weight delineates the edges of progressively more distant objects from the plane of the cut.
- The lightest line weights represent surface lines. These lines do not signify any change in form. They simply represent the visual pattern or texture of wall planes and other vertical surfaces parallel to the picture plane.



Woodland Chapel, Stockholm, Sweden, 1918–1920, Erik Gunnar Asplund





Poché

In a line-and-tone or pure tone drawing, we emphasize the shape of cut elements with a tonal value that contrasts with the spatial field of the building section. The purpose is to establish a clear figure-ground relationship between solid matter and spatial void—between container and contained.

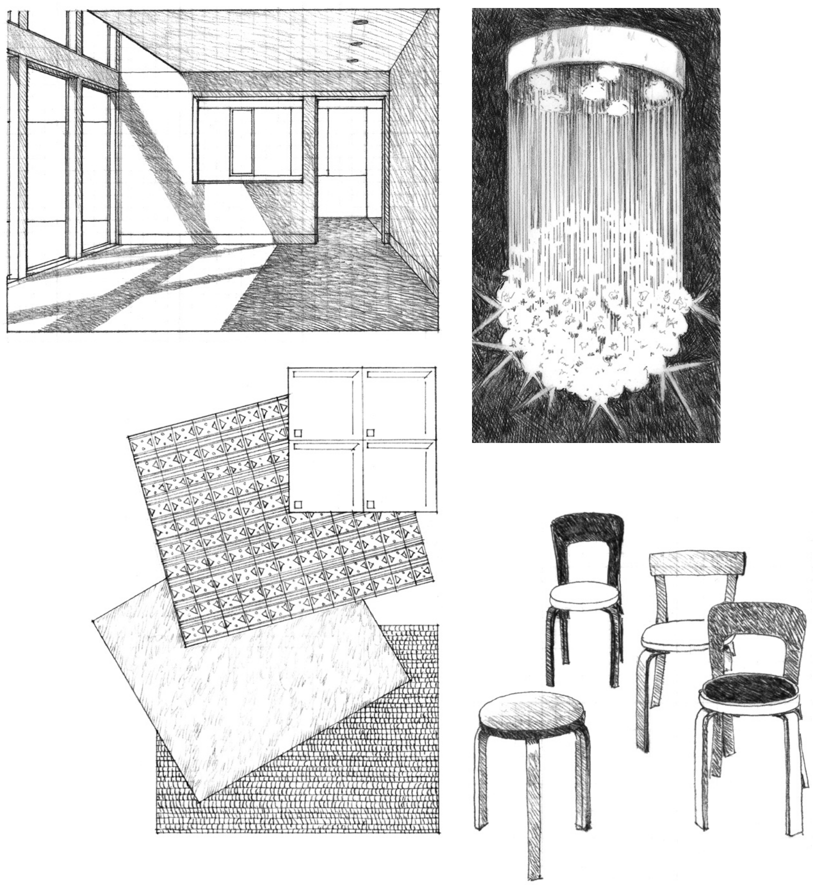
It is typical to blacken or poché the floor, wall, and roof elements that are cut in small-scale building sections. If only a moderate degree of contrast with the drawing field is desired, use a middle-gray value to illuminate the shape of the cut elements. This is especially important in large-scale sections when large areas of black can carry too much visual weight or create too stark a contrast. However, if vertical elements, such as wall patterns and textures, give the field of the drawing a tonal value, a dark gray or black tone may be necessary to produce the desired degree of contrast between solid matter and spatial void. In this value scheme, use progressively lighter values for elements as they recede into the third dimension.

A second approach is to reverse the value scheme and render the cut elements as a white figure against a spatial field of darker tonal values. Reversing the normal dark-light pattern in this way emphasizes the figure of the contained space. Be sure, however, that there is enough tonal contrast to distinguish the cut elements. If necessary, outline the profile of the cut elements with a heavy line weight, and use progressively darker values for elements or planes as they recede into the third dimension.

Remember that the ground mass is also cut in building and site sections. The tonal value of the cut elements should, therefore, continue into the supporting ground mass. If we show a building's foundation in a section drawing, we should be careful to delineate its walls and footings below grade as an integral part of the surrounding ground mass. We must represent the substructure in such a way that we maintain the reading that the vertical plane of the section cuts through both the foundation and the surrounding mass of the earth.

14 Allied Disciplines:

Interior Design



How Is Interior Design Related to Architecture?

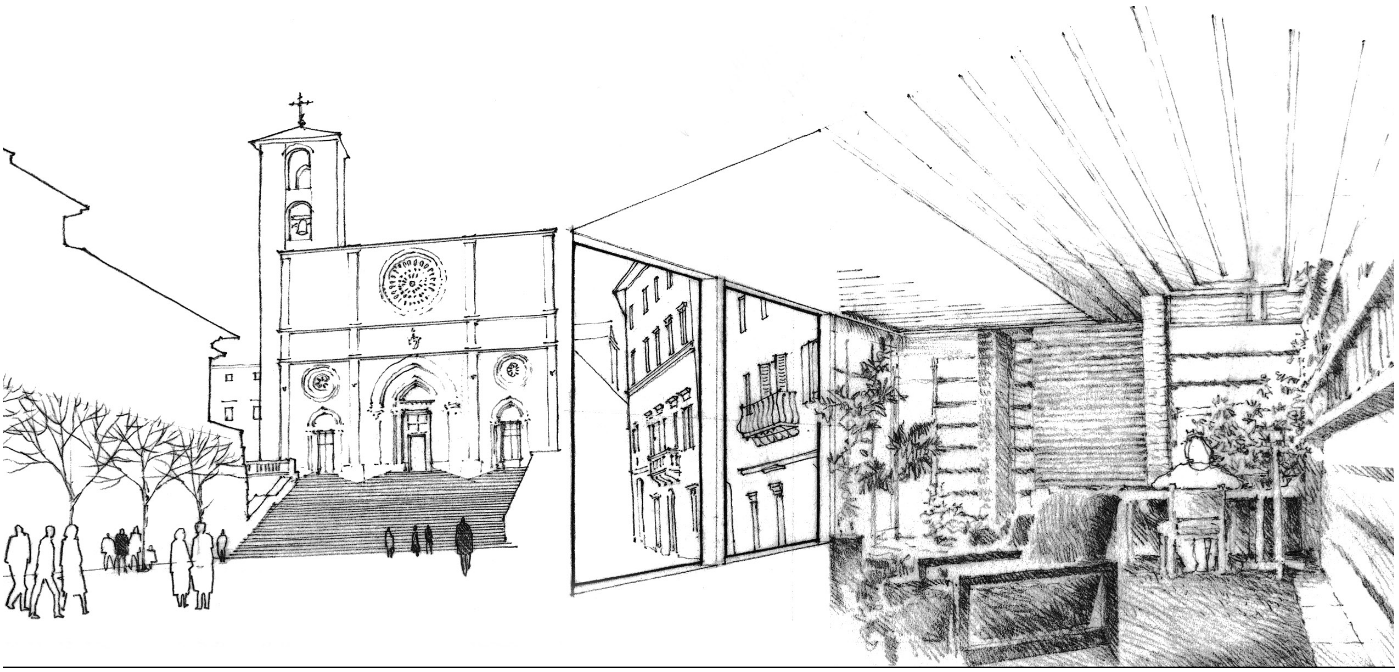
Interior design and architecture are allied design disciplines. They share many of the same priorities.

The two disciplines are related in the following ways:

- They are concerned with space as an inhabitable, constructed environment.
- They produce outcomes that are a result of a design process that combines knowledge and technique.
- They are both limited by similar design constraints of size, budget, timeframe, and client demands.

In contemporary architectural practice, it very common to have design teams composed of both architects and interior designers (sometimes interior architects). The distinction between the two disciplines is usually blurred as they collaborate to deliver effective buildings.

The notion that the inside of a building is the domain of the interior designer and the outside is the responsibility of an architect is a misconception. Design decisions made regarding interior spaces usually have consequences for the exterior of the building. For example, the decision to have light come into a space in a particular way demands a window—which contributes to the exterior facade.



A better distinction between the two might be that where architects begin the design process at the scale of a room and progress up (considering the entire building or even a city district), interior designers begins at the scale of a room and progress down (considering such intricate details as textile patterns and millwork).

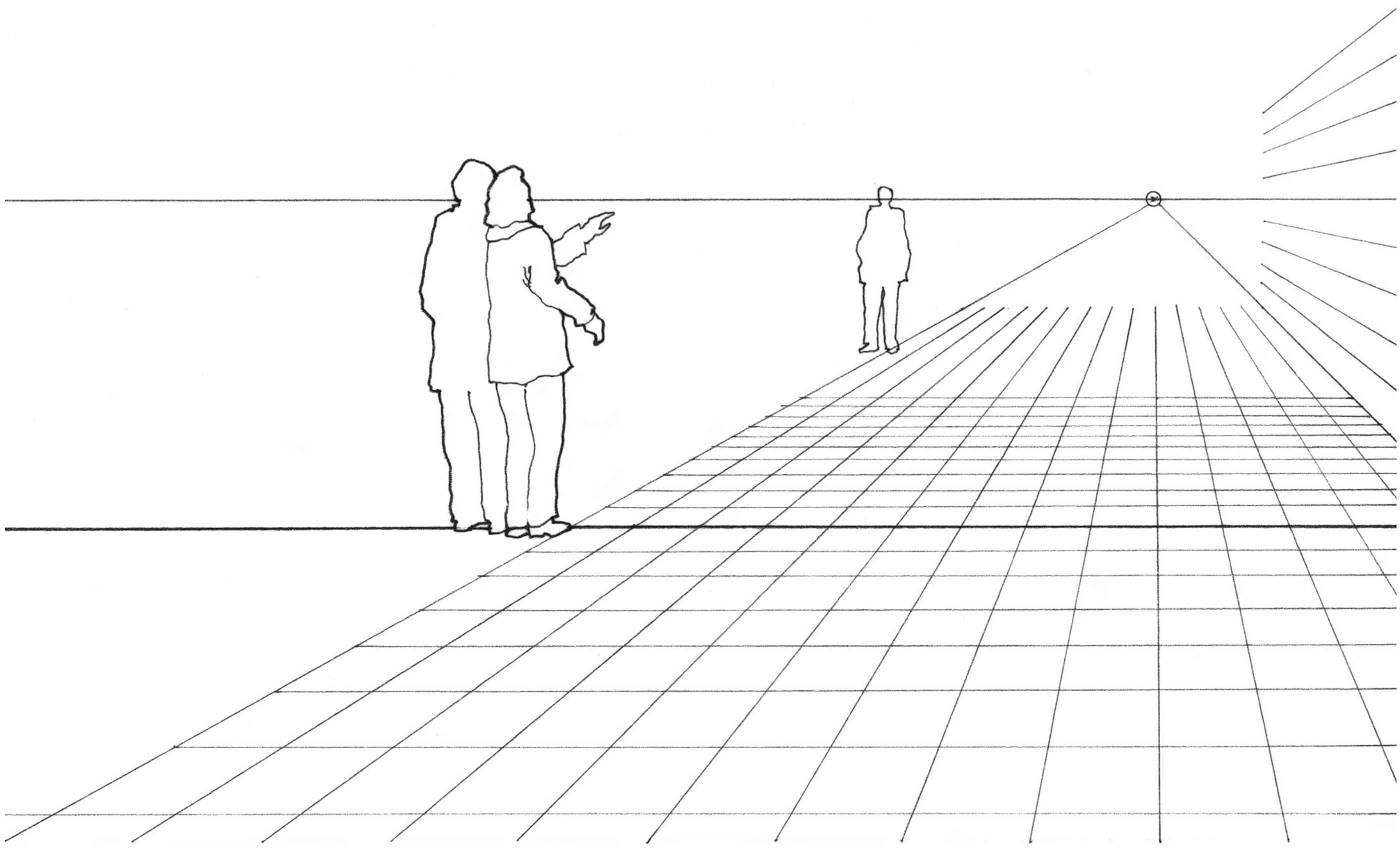
While this better represents the relationship between architecture and interior design, it is still an oversimplification. Members of both disciplines share an interest in design that translates from the smallest to the largest considerations. This often leads to their roles being reversed.

This chapter will briefly discuss interior design as a profession closely related to architecture. It should not be confused with interior decorating because its responsibilities extend far beyond the scope of décor.

Space

Space is a prime ingredient in the designer's palette and the quintessential element in interior design. Through the volume of space we not only move but also see forms, hear sounds, feel gentle breezes and the warmth of the sun, and smell the fragrances of flowers in bloom. Space inherits the sensual and aesthetic characteristics of the elements in its field.

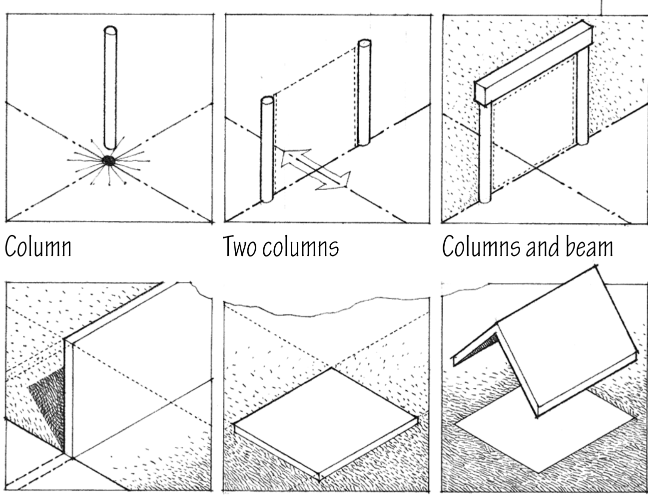
Space is not a material substance like stone and wood. It is inherently formless and diffuse. Universal space has no defining borders. Once an element is placed in its field, however, a visual relationship is established. As other elements are introduced into the field, multiple relationships are established between the space and the elements as well as among the elements themselves. Space is formed by our perception of these relationships.



Architectural Space

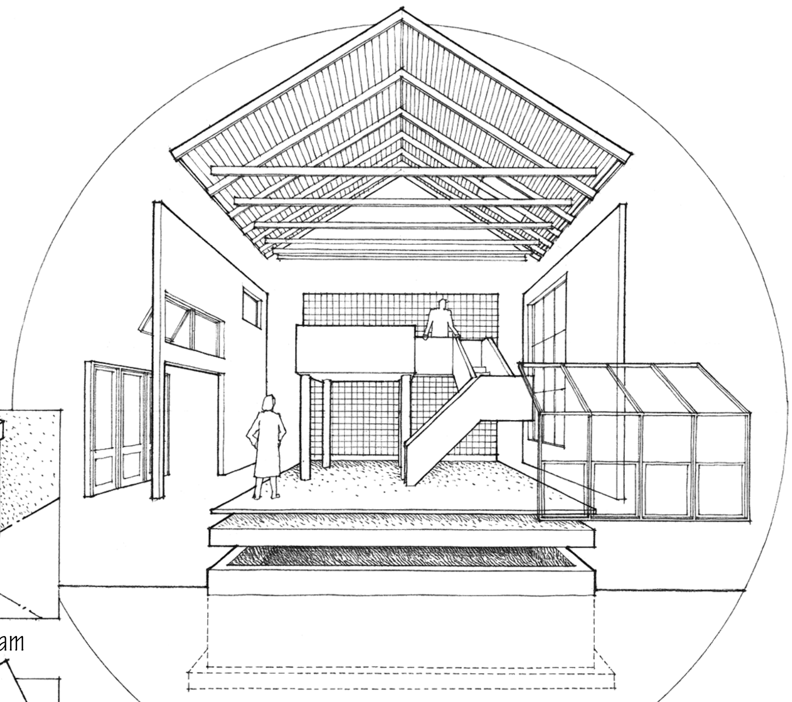
The geometric elements—point, line, plane, and volume—can be arranged to articulate and define space. In architecture, these fundamental elements become linear columns and beams, and planar walls, floors, and roofs.

- A column marks a point in space and makes it visible in three dimensions.
- Two columns define a spatial membrane through which we can pass.
- Supporting a beam, the columns delineate the edges of a transparent plane.
- A wall, an opaque plane, marks off a portion of amorphous space and separates here from there.
- A floor defines a field of space with territorial boundaries.
- A roof provides shelter for the volume of space beneath it.



Column Two columns Columns and beam

Wall Floor Roof



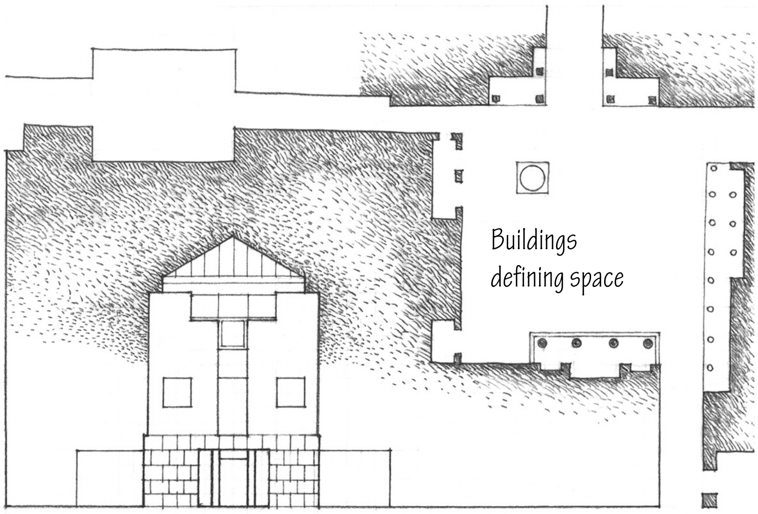
Defining Space

In architectural design, these elements are organized to give a building form, differentiate between inside and outside, and define the boundaries of interior space.

A building's form, scale, and spatial organization are the designer's response to a number of conditions—functional planning requirements, technical aspects of structure and construction, economic realities, and expressive qualities of image and style. In addition, the architecture of a building should address the physical context of its site and the exterior space.

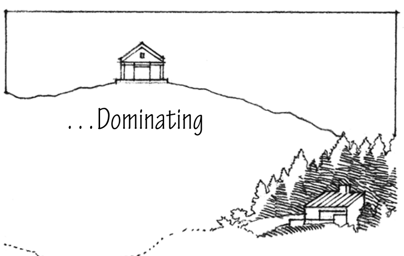
A building can be related to its site in several ways. It can merge with its setting or dominate it. It can surround and capture a portion of exterior space. One of its faces can be made to address a feature of its site or define an edge of exterior space. In each case, due consideration should be given to the potential relationship between interior and exterior space, as defined by the nature of a building's exterior walls.

Buildings affect and are affected by conditions of their sites and the wider environment. Selecting and developing sites to reduce site disturbance, stormwater runoff, heat island effects, and light pollution contribute to sustainable design.



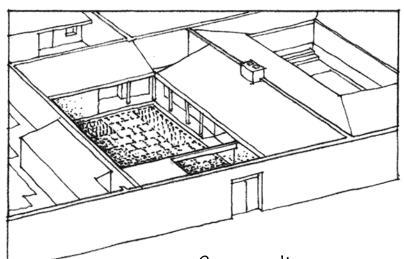
A building in space

Buildings

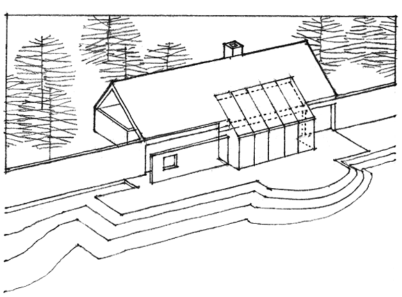


. . . Dominating

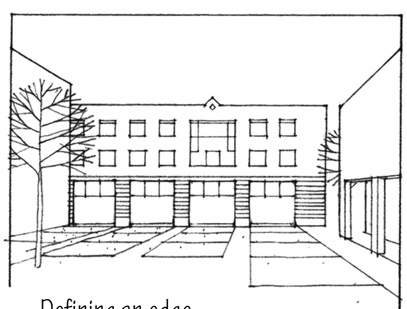
. . . Merging



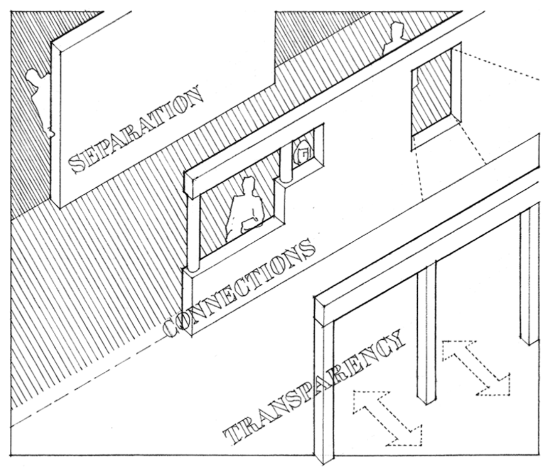
. . . Surrounding



. . . Fronting



. . . Defining an edge



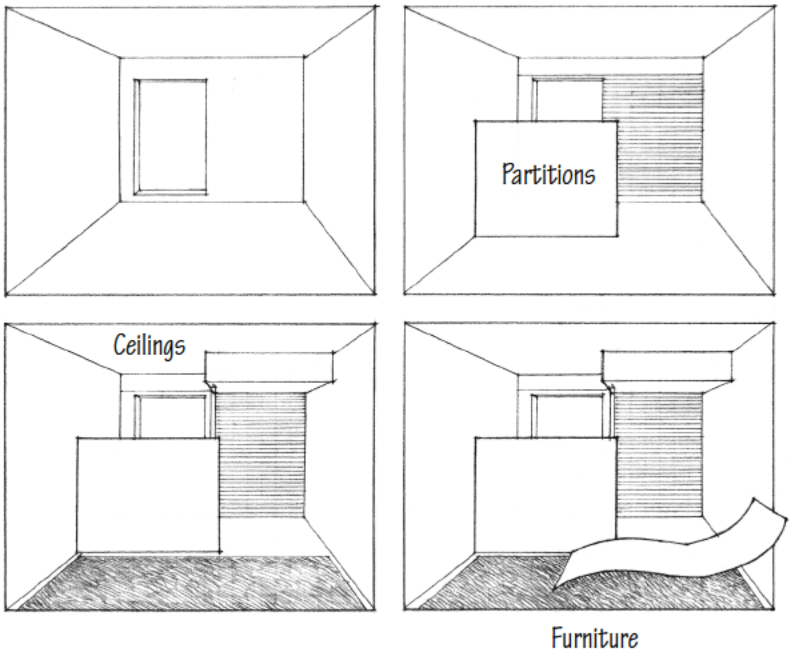
Exterior Walls

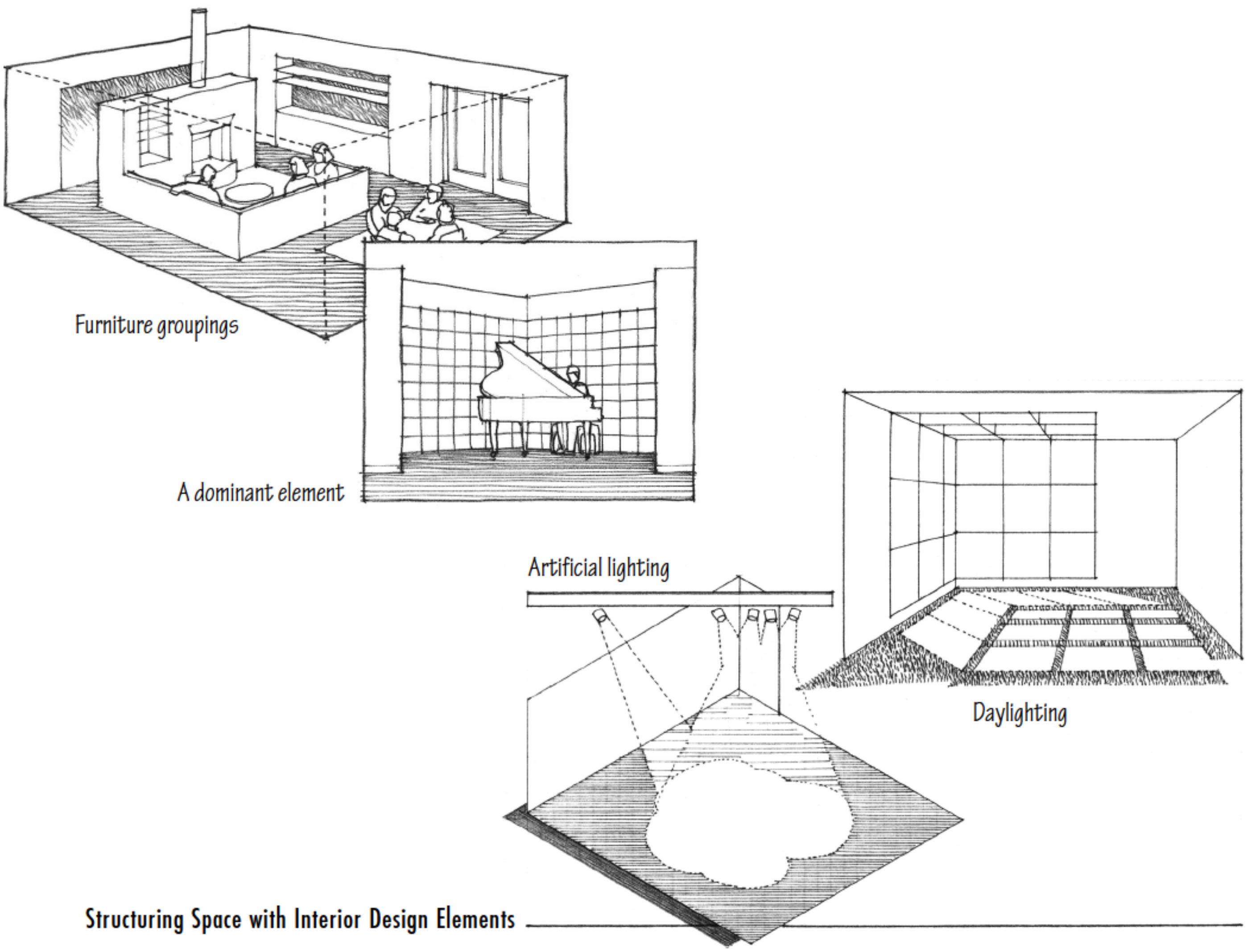
Shaping Interior Space

While a building's structural system sets up the basic form and pattern of its interior spaces, these spaces are ultimately structured by the elements of interior design. The term *structure* is not used here in the sense of physical support. It refers to the selection and arrangement of interior elements such that their visual relationships define and organize the interior space of a room.

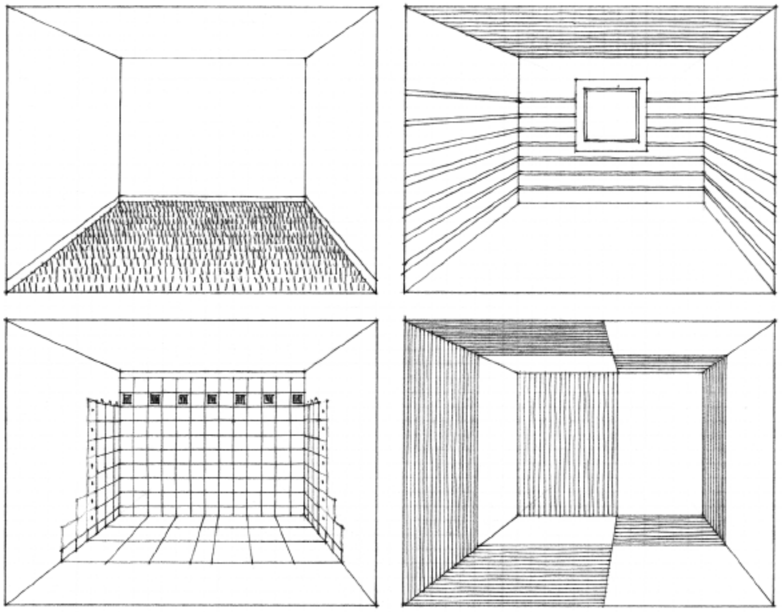
Non-load-bearing partitions and suspended ceilings are often used to define or modify space within the structural framework or shell of a building.

The color, texture, and pattern of wall, floor, and ceiling surfaces affect our perception of their relative positions in space and our awareness of the room's dimensions, scale, and proportion.





Structuring Space with Interior Design Elements



Color, texture, and pattern

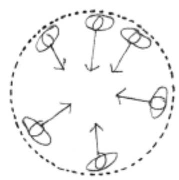
Structuring Space with Interior Design Elements

Within a large space, the form and arrangement of furnishings can divide areas, provide a sense of enclosure, and define spatial patterns.

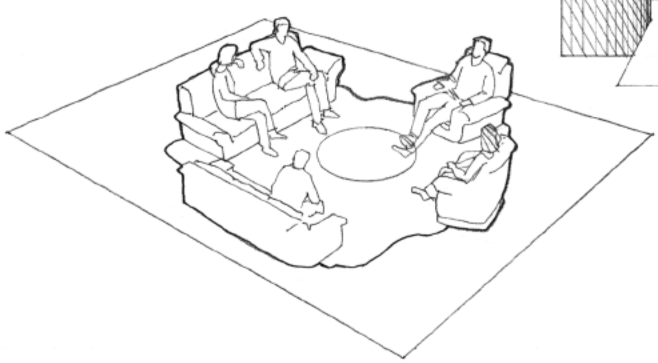
Lighting, and the light and dark patterns it creates, can call our attention to one area of a room, deemphasize others, and thereby create divisions of space.

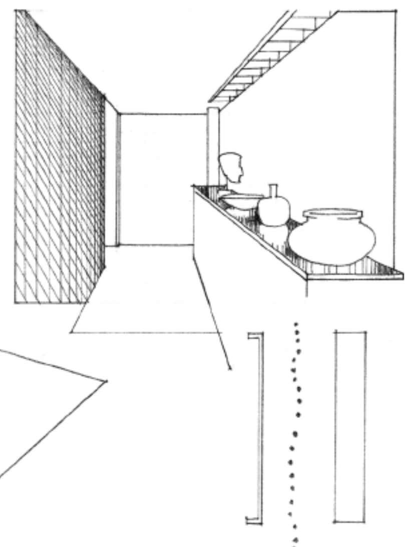
Even the acoustic nature of a room's surfaces can affect the apparent boundaries of a space. Soft, absorbent surfaces muffle sounds and can diminish our awareness of the physical dimensions of a room. Hard surfaces that reflect sounds within a room help to define its physical boundaries. Echoes can suggest a large volume.

Finally, space is structured by how we use it. The nature of our activities and the rituals we develop in performing them influence how we plan, arrange, and organize interior space.

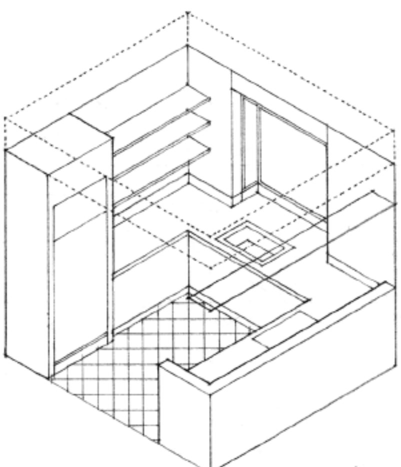


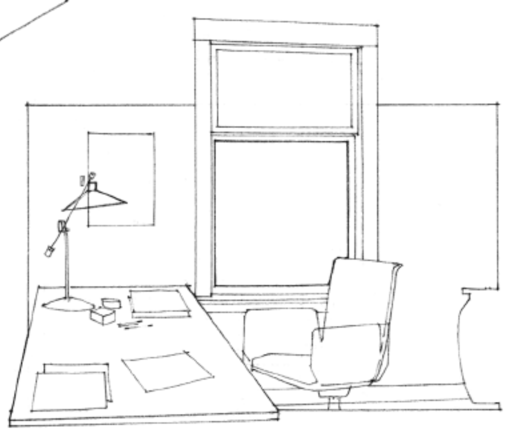
Communication





Movement

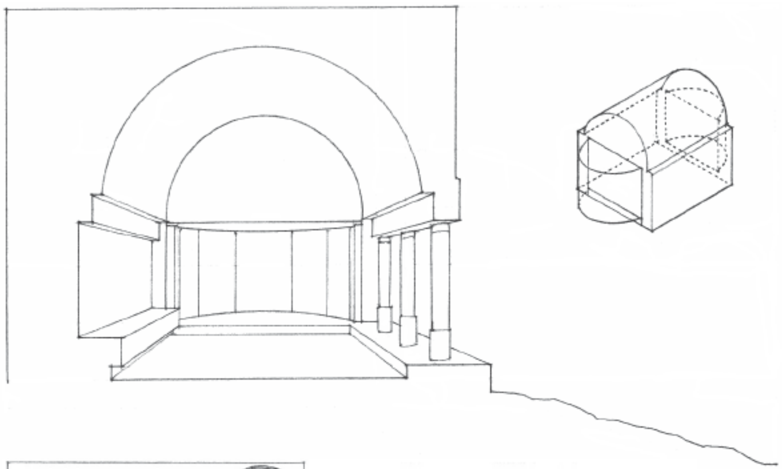


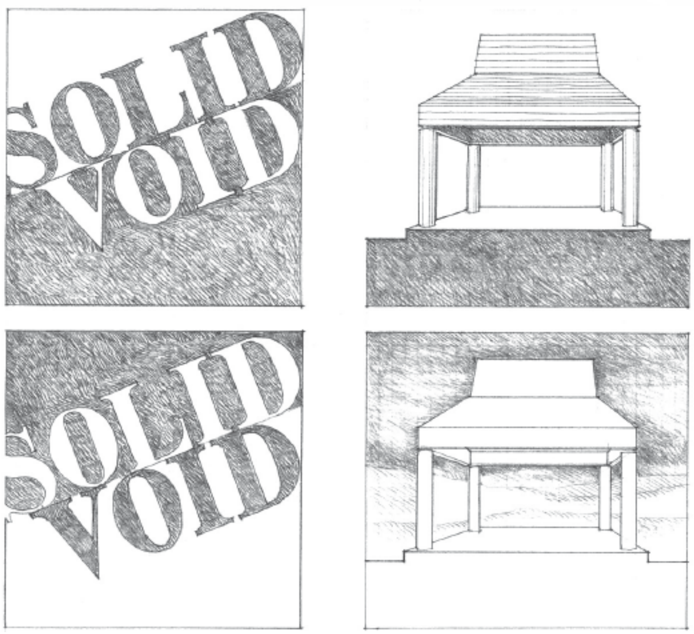


Individual and group activities

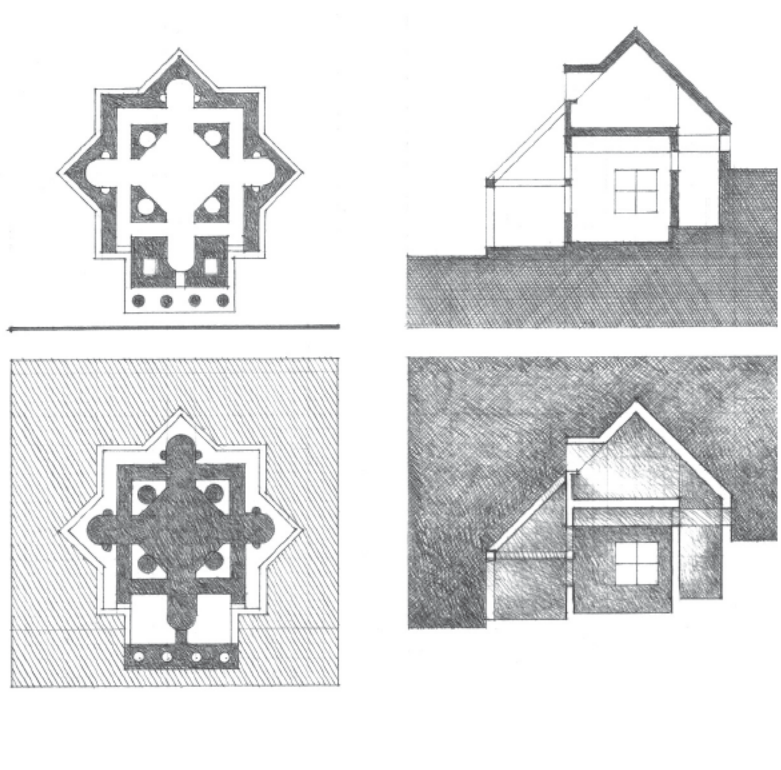
Figure-Ground Relationships

Interior spaces are formed first by a building's structural system, further defined by wall and ceiling planes, and related to other spaces by windows and doorways. Every building has a recognizable pattern of these elements and systems. Each pattern has an inherent geometry that molds or carves out a volume of space into its likeness.



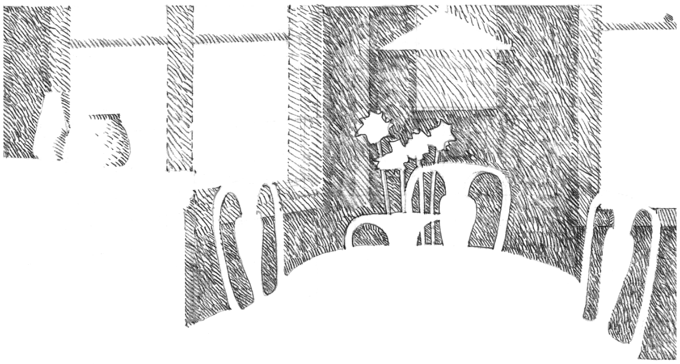


It is useful to be able to read this figure-ground relationship between the form of space-defining elements and that of the space defined. Either the structure or the space can dominate this relationship. Whichever appears to dominate, we should be able to perceive the other as an equal partner in the relationship.



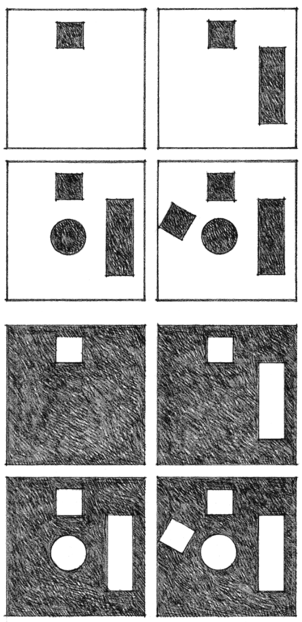
Spatial Form

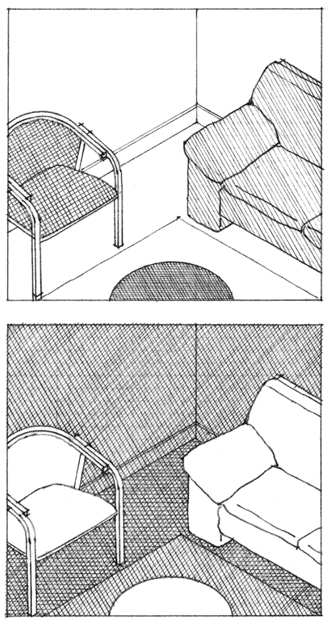
It is equally useful to see this alternating figure-ground relationship occurring as interior design elements, such as tables and chairs, are introduced and arranged within an interior space.

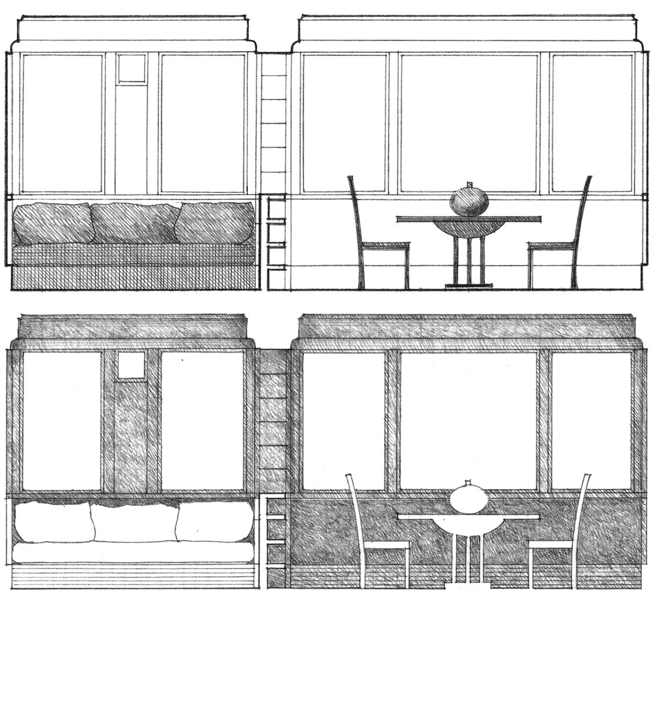


When a chair is placed in a room, it not only occupies space, but also creates a spatial relationship between itself and the surrounding enclosure. We should see more than the form of the chair. We should also recognize the form of the space surrounding the chair after it has filled some of the void.

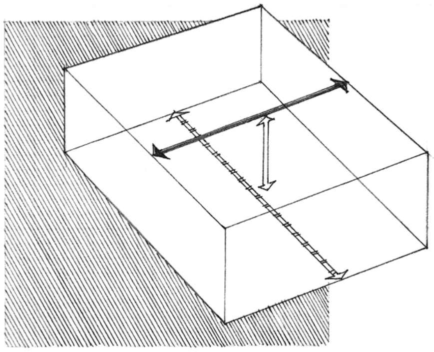
As more elements are introduced into the pattern, the spatial relationships multiply. The elements begin to organize themselves into sets or groups, each of which not only occupy space, but also define and articulate the spatial form.





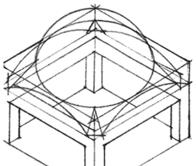


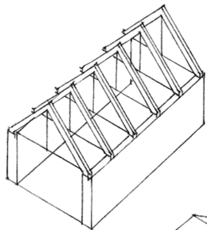
Spatial Dimensions

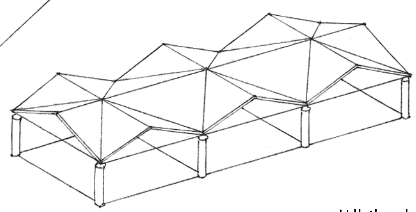


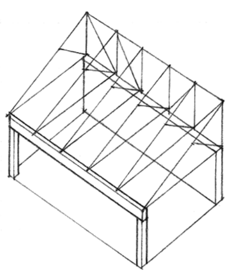
The dimensions of interior space, like spatial form, are directly related to the nature of a building's structural system—the strength of its materials and the size and spacing of its members. The dimensions of a space, in turn, determine a room's proportion and scale and influence how it is used.

One horizontal dimension of space, its width, has traditionally been limited by the materials and techniques used to span it. Today, given the necessary economic resources, almost any architectural structure is technically possible. Wood or steel beams and concrete slabs can span up to 30 feet (9 m). Wood or steel trusses can span even farther, up to 100 feet (30 m) or more. Longer roof spans are possible with space frames and a variety of curved structures, such as domes, suspension systems, and membranes supported by air pressure.



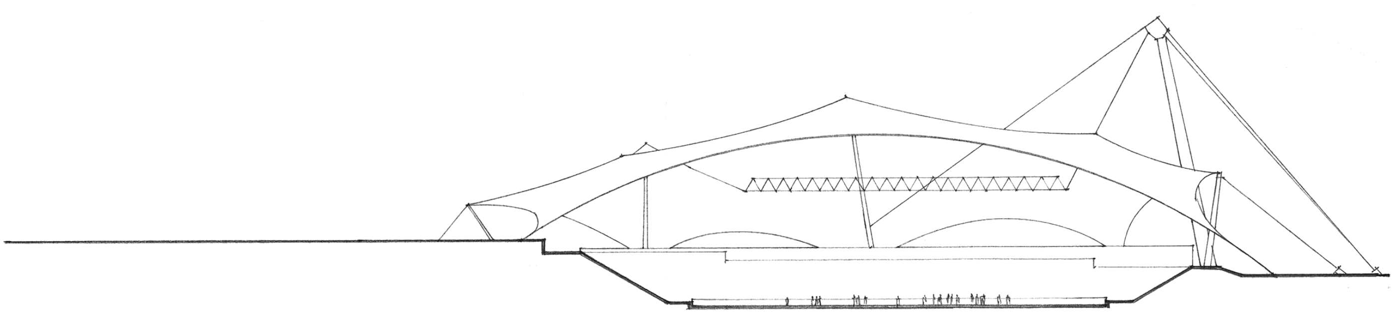


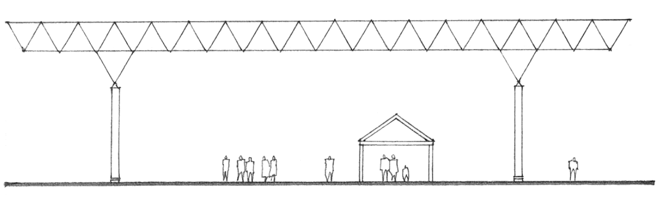




While the width of an interior space may be limited by structural necessity, it should be established by the requirements of those who use the space and their need to set boundaries for themselves and their activities.

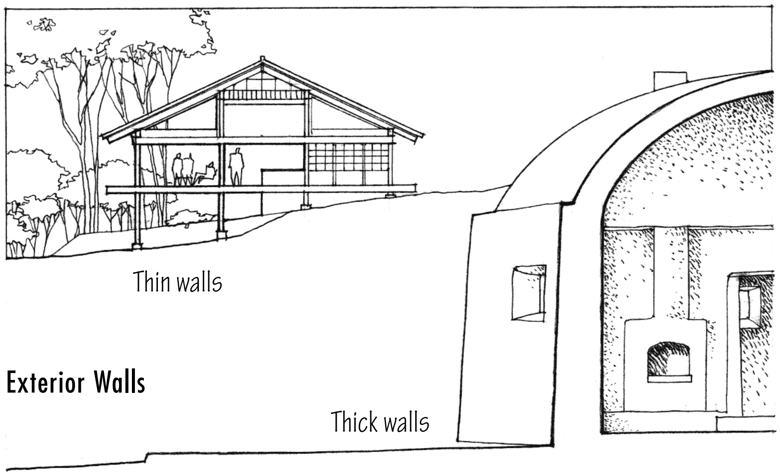
Building designers have traditionally developed spatial relationships by sketching and model building. Computer-aided design and drafting (CADD) and building information management (BIM) software systems are changing the way that building designers work. These computer technologies allow designers to build interactive three-dimensional computer models of buildings and to coordinate building systems as they design.





Outside to Inside

A building's exterior walls constitute the interface between our interior and exterior environments. In defining both interior and exterior space, they determine the character of each. They may be thick and heavy and express a clear distinction between a controlled interior environment and the exterior space from which it is isolated. They may be thin, or even transparent, and attempt to merge inside and outside.

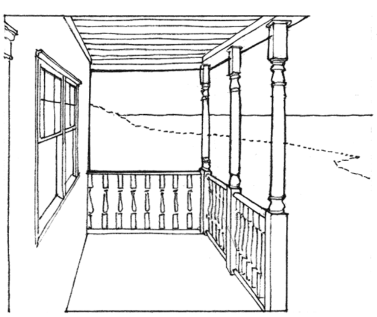


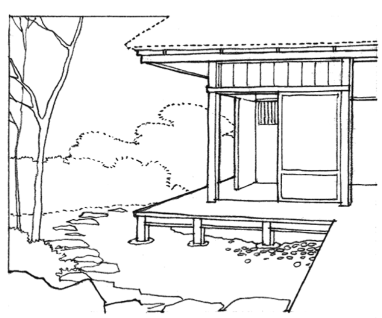
Exterior Walls

Windows and doorways, the openings that penetrate a building's exterior walls, are the spatial transitions between exterior and interior space. Their scale, character, and composition often tell us something about the nature of the interior spaces that lie between them.

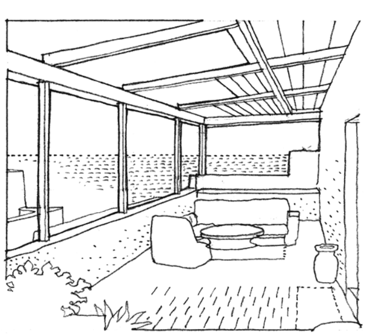
Spatial Transitions

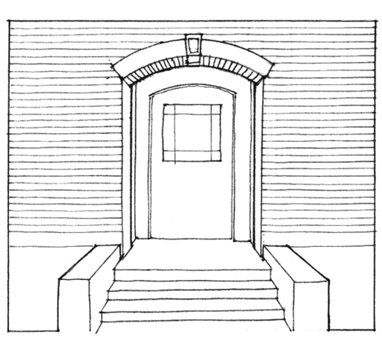
Special transitional spaces, belonging to both the outside world and the inside, can be used to mediate between the two environments. Familiar examples include a porch, a veranda, or an arcaded gallery.





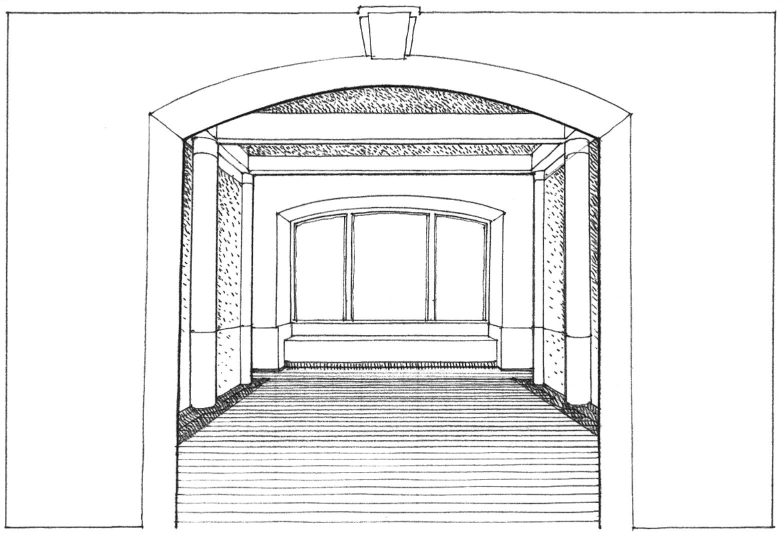
Many single-family residences have steps at all entrances that present barriers to people with physical disabilities. Visitability is a movement to construct new homes so that they can be readily lived in and visited by people with mobility impairments.





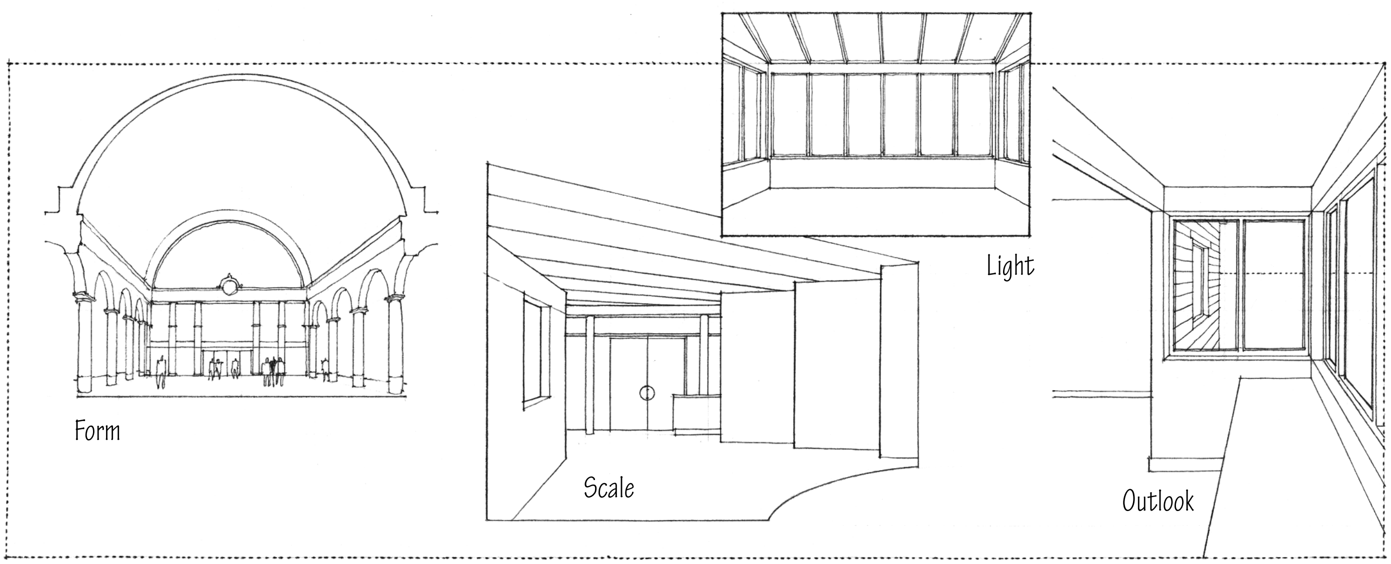
Interior Space

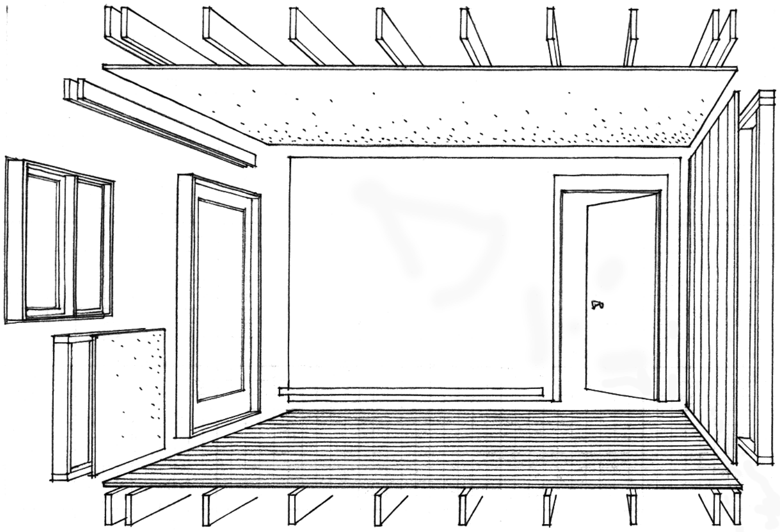
Upon entering a building, we sense shelter and enclosure. This perception is the result of the bounding floor, wall, and ceiling planes of interior space. These are the architectural elements that define the physical limits of rooms. They enclose space, articulate its boundaries, and separate it from adjoining interior spaces and the outside.



Entrances mark the transition from here to there.

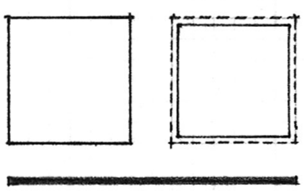
Floors, walls, and ceilings do more than mark off a simple quantity of space. Their form, configuration, and pattern of window and door openings also imbue the defined space with certain spatial or architectural qualities. We use terms such as grand hall, loft space, sun room, and alcove not simply to describe how large or small a space is, but also to characterize its scale and proportion, its quality of light, the nature of its enclosing surfaces, and how it relates to adjacent spaces.



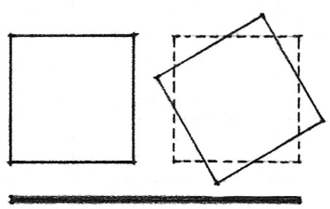


Spatial Qualities

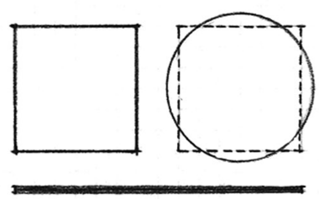
Interior design necessarily goes beyond the architectural definition of space. In planning the layout, furnishing, and enrichment of a space, the interior designer should be acutely aware of its architectural character as well as its potential for modification and enhancement. The design of interior spaces requires, therefore, an understanding of how they are formed by the building systems of structure and enclosure. With this understanding, the interior designer can effectively elect to work with, continue, or even offer a counterpoint to the essential qualities of an architectural space.



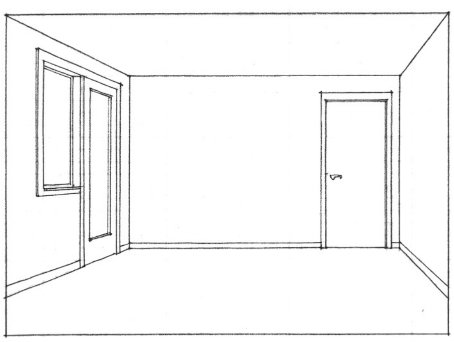
Continuation



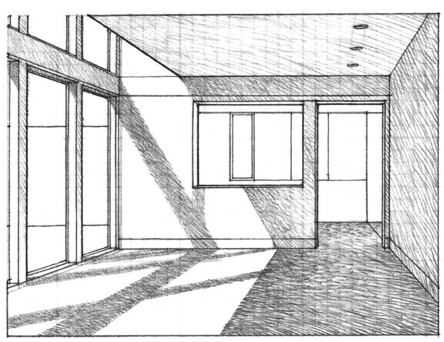
Contrast



Counterpoint



The basic shell



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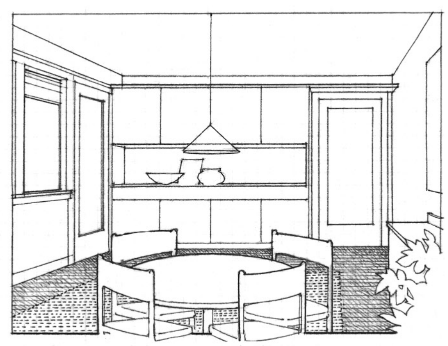


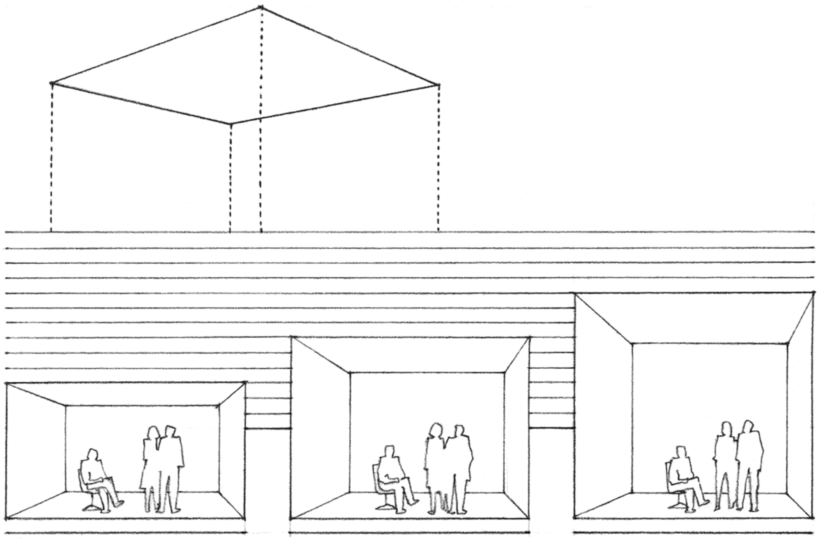
. . . or through interior design

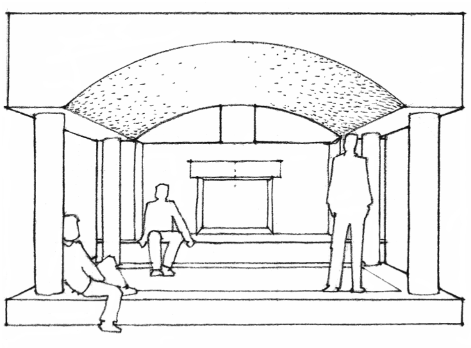
Interior Space

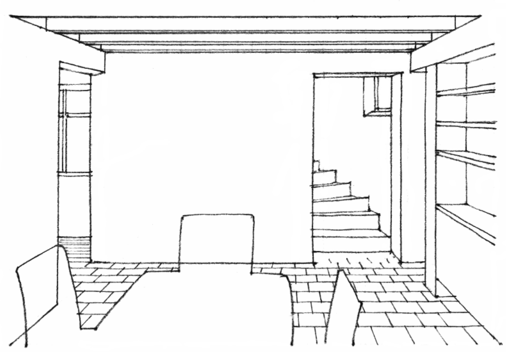
The Vertical Dimension of Space

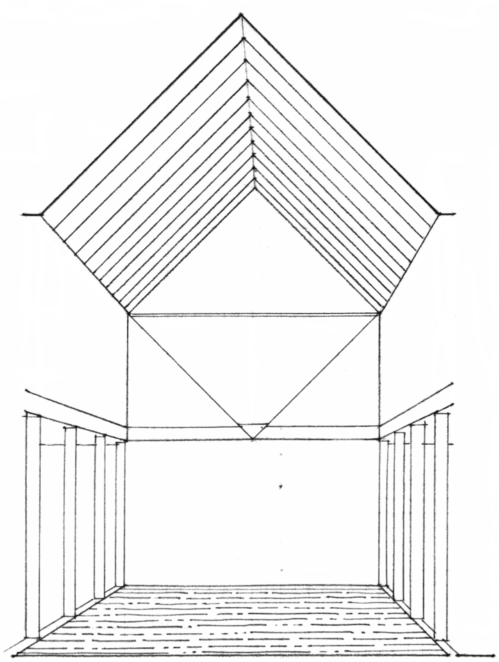
The third dimension of interior space, its height, is established by the ceiling plane. This vertical dimension is as influential as the horizontal dimensions of a space in forming the spatial quality of a room.

While our perception of a room's horizontal dimensions is often distorted by the foreshortening of perspective, we can more accurately sense the relationship between the height of a space and our own body height. A measurable change in the height of a ceiling seems to have a greater effect on our impression of a space than a similar change in its width or length.







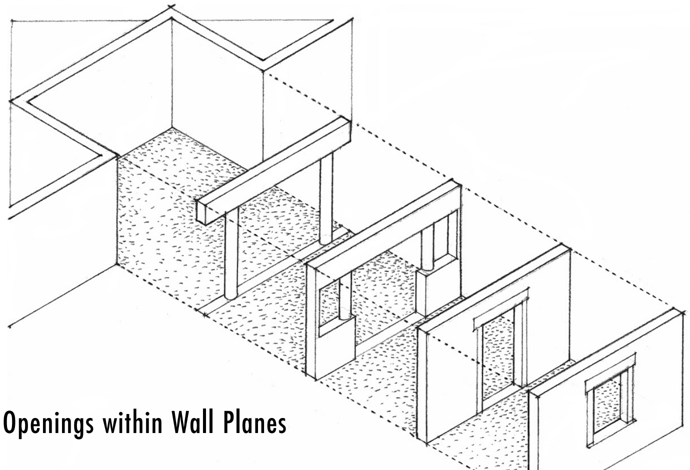


Varying the ceiling height can have a powerful effect on the perceived scale of a space.

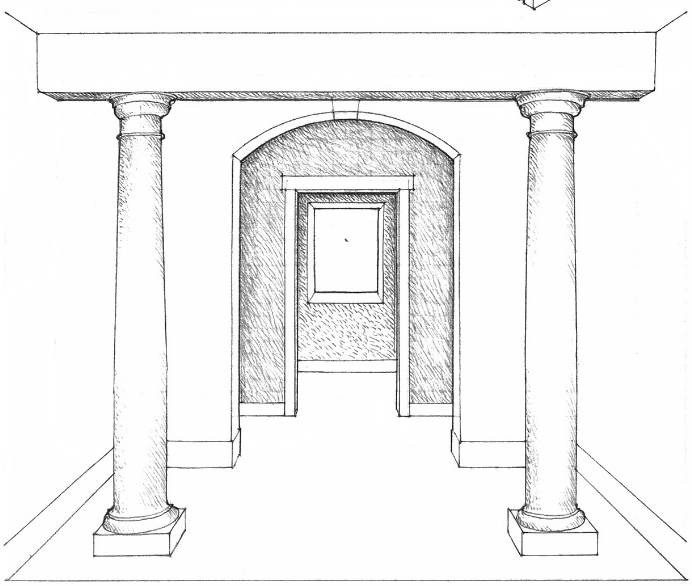
Spatial Transitions

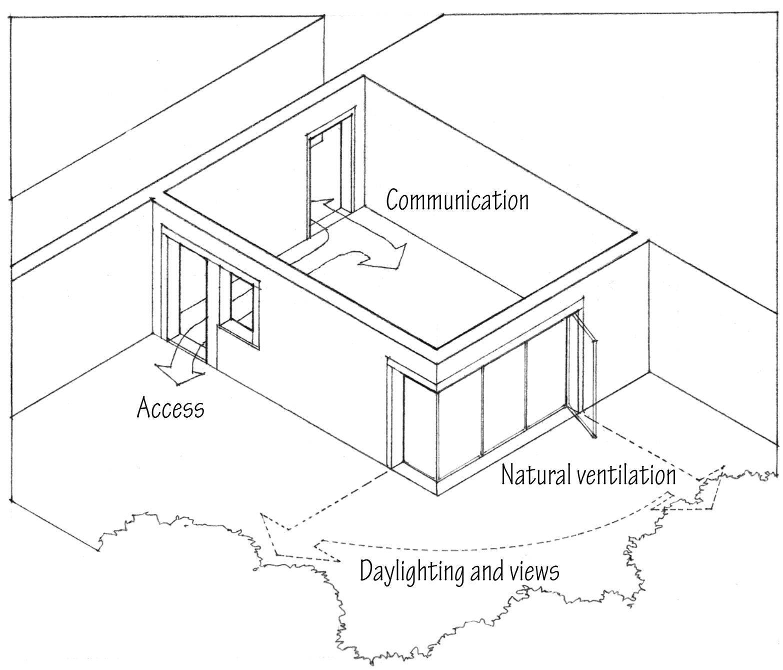
Although individual spaces may be designed and formed for a certain purpose or to house certain activities, they are gathered together within a building's enclosure because they are functionally related to one another, they are used by a common group of people, or they share a common purpose. How interior spaces are related to one another is determined not only by their relative position in a building's spatial pattern, but also by the nature of the spaces that connect them and the boundaries they have in common.

Floor, wall, and ceiling planes serve to define and isolate a portion of space. Of these, the wall plane, being perpendicular to our normal line of sight, has the greatest effect as a spatial boundary. It limits our visual field and serves as a barrier to our movement. Openings created within the wall plane for windows and doorways reestablish contact with the surrounding spaces from which the room was originally cut.



Openings within Wall Planes

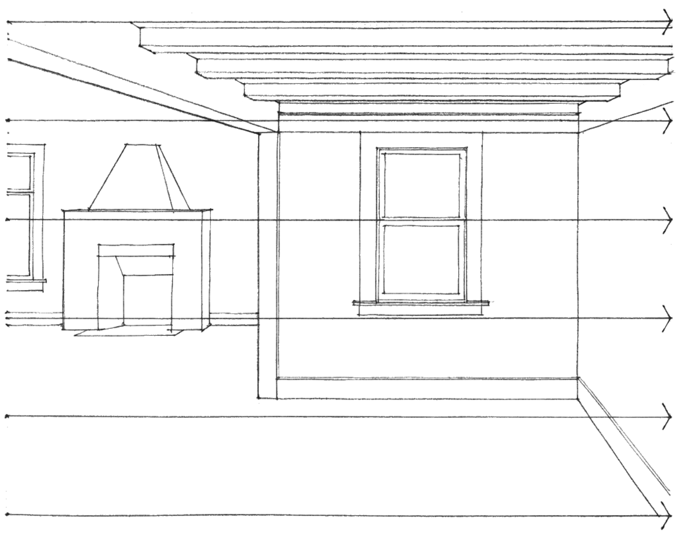




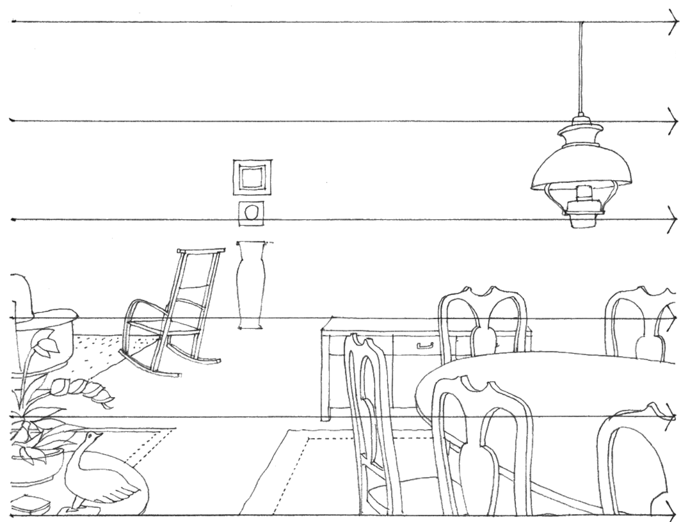
Interior Design

Interior design is the planning, layout, and design of the interior spaces within buildings. These physical settings satisfy our basic need for shelter and protection, set the stage for and influence the shape of our activities, nurture our aspirations and express the ideas that accompany our actions, and affect our outlook, mood, and personality. The purpose of interior design, therefore, is the functional improvement, aesthetic enrichment, and psychological enhancement of the quality of life in interior spaces.

The Planning, Layout, and **Design** of the Parts

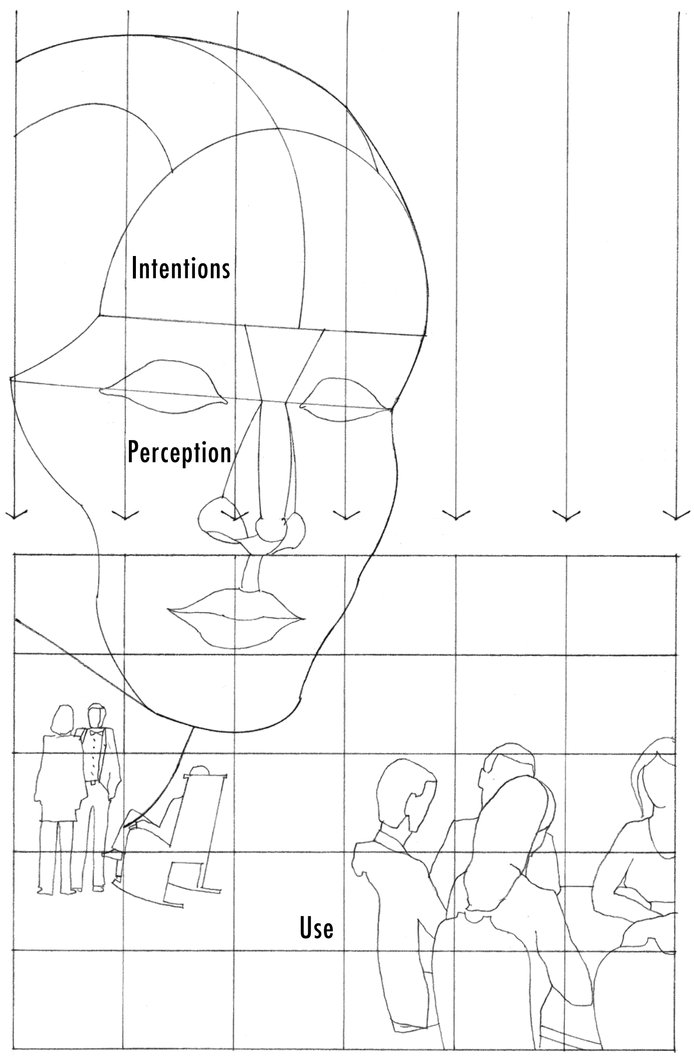


The Architectural Context

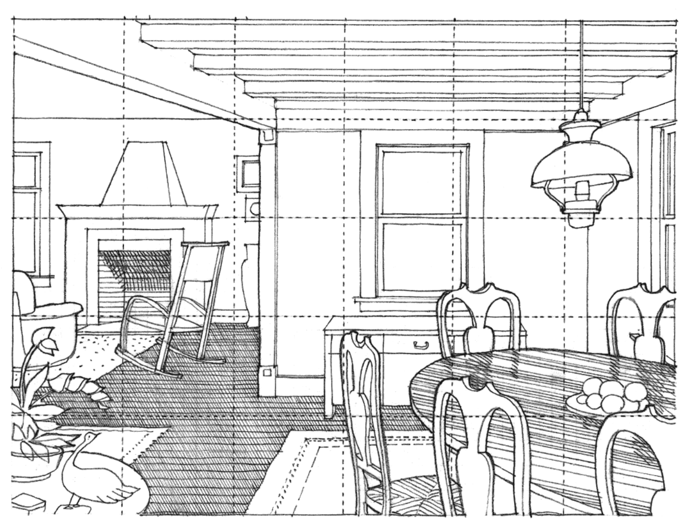


Interior Elements

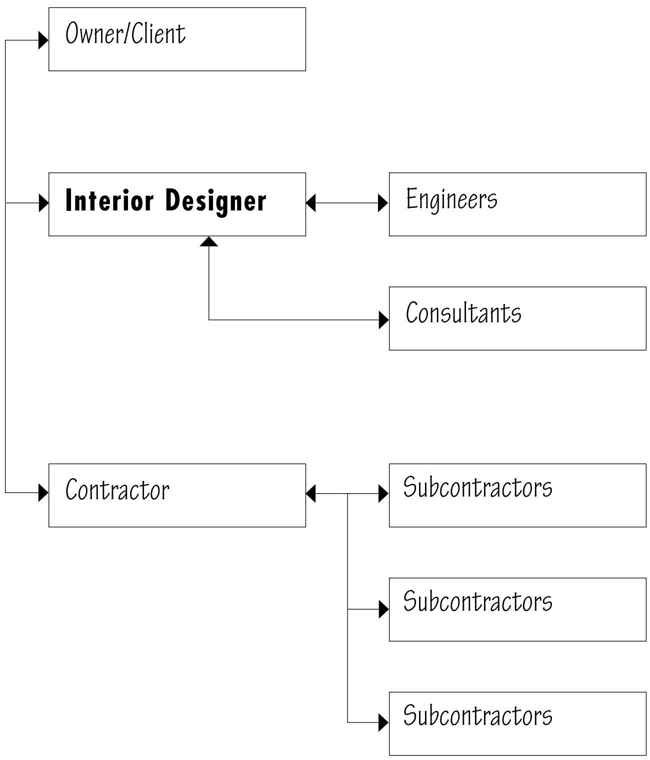
The purpose of any design is to organize its parts into a coherent whole in order to achieve certain goals. In interior design, selected elements are arranged into three-dimensional patterns according to functional, aesthetic, and behavioral guidelines. The relationships among the elements established by these patterns ultimately determine the visual qualities and functional fitness of an interior space and influence how we perceive and use it.



into a Whole



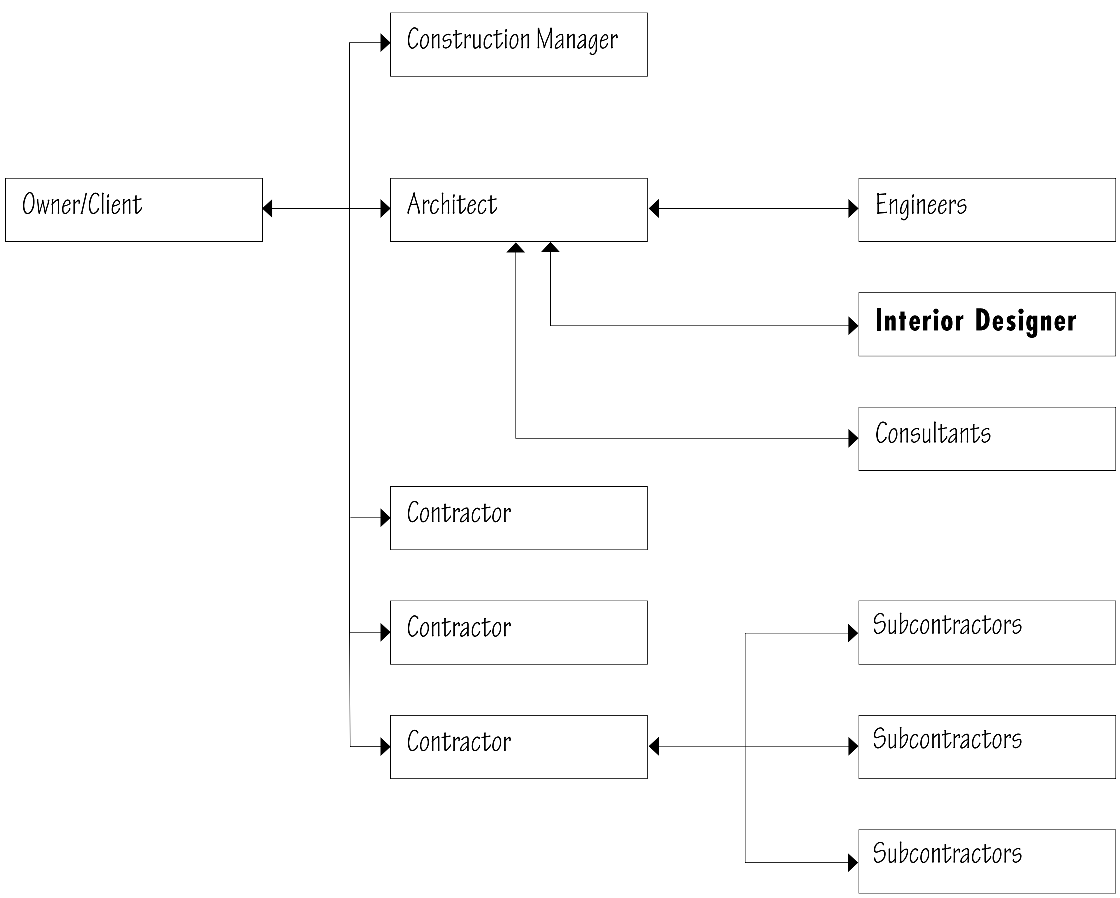
The Interior Environment



The Design and Construction Team

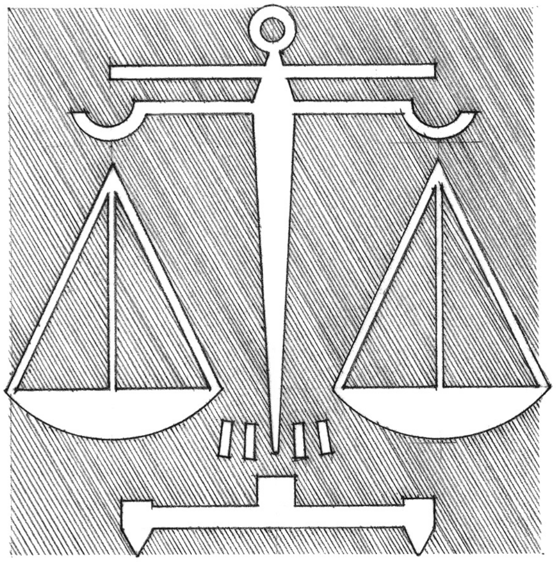
The development of architectural forms and environmental systems for any building has implications for the interior designer, just as the information the interior designer collects about the client, the space, and the intended activities has implications for the work of the other members of the design team.

The interior designer may be working as a sole practitioner; collaborating with other designers, architects, and design specialists in a larger design firm, or he or she may be serving as a consultant to an architectural firm. In any case, the interior designer is likely to have contact with architects, engineers, and other consultants in other firms. In addition, the interior designer will work with client representatives, including facilities managers, administrators, and end users. The interior designer is often the liaison between the client and the sources for finishes or furnishings. During construction, the interior designer is also in contact with contractors and suppliers. All of these members of the design and construction team should strive to maintain an atmosphere of communication, cooperation, and mutual respect.



Design Criteria

In defining and analyzing a design problem, one also develops goals and criteria by which the effectiveness of a solution can be measured. Regardless of the nature of the interior design problem being addressed, there are several criteria with which we should be concerned.



Function and Purpose

First, the intended function of the design must be satisfied and its purpose fulfilled.

Utility, Economy, and Sustainability

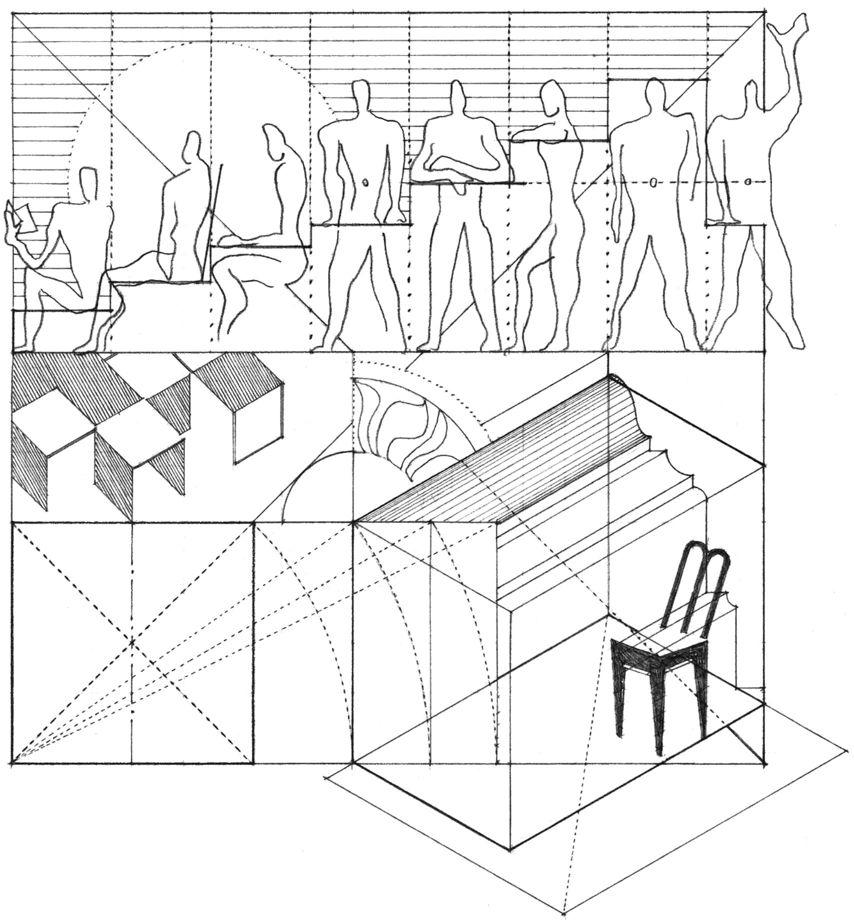
Second, a design should exhibit utility, honesty, economy, and sustainability in its selection and use of materials.

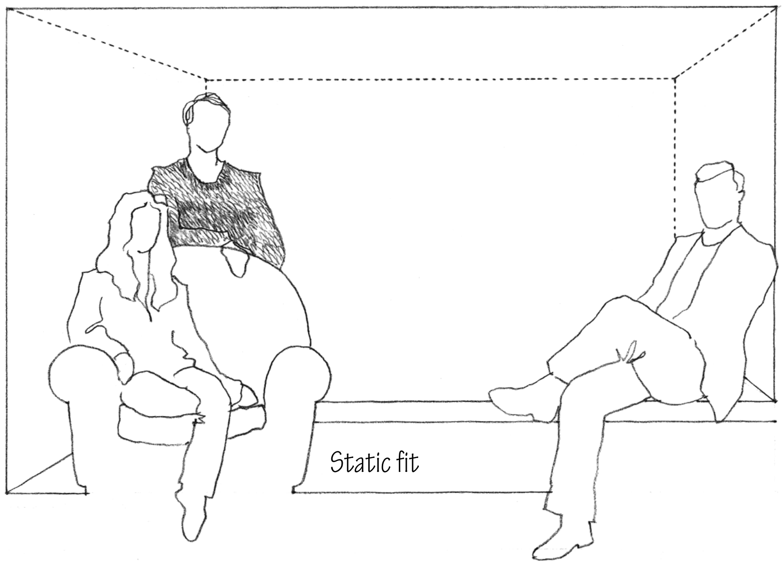
Form and Style

Third, the design should be aesthetically pleasing to the eye and our other senses.

Image and Meaning

Fourth, the design should project an image and promote associations that carry meaning for the people who use and experience it.





Static fit

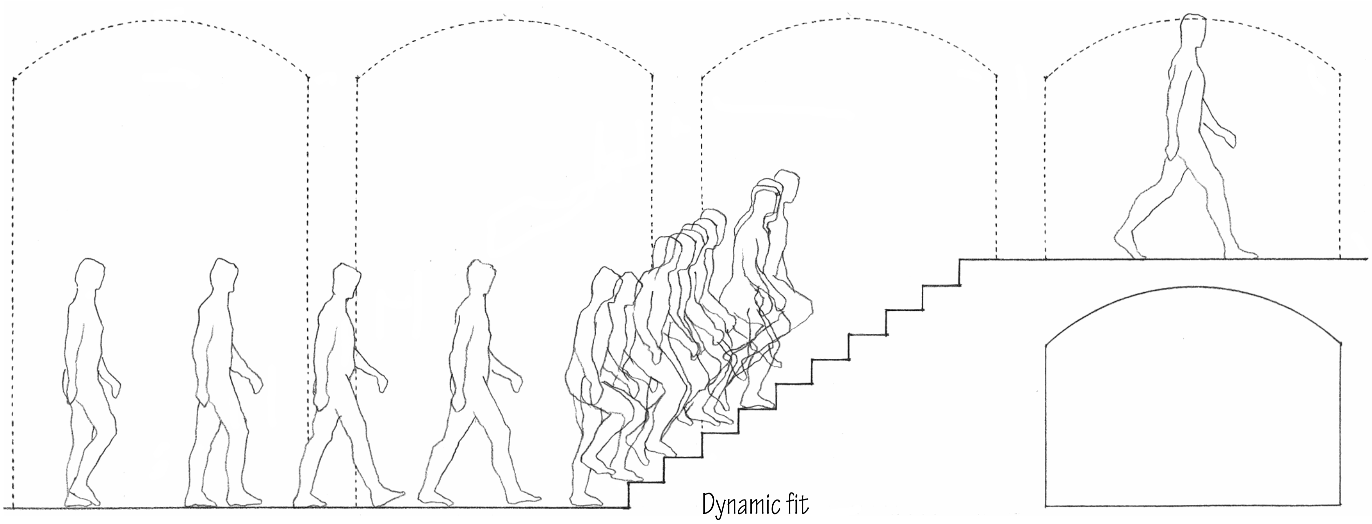
Human Factors

The interior spaces of buildings are designed as places for human movement, activity, and repose. There should be, therefore, a fit between the form and dimensions of interior space and our own body dimensions. This fit can be a static one as when we sit in a chair, lean against a railing, or nestle within an alcove.

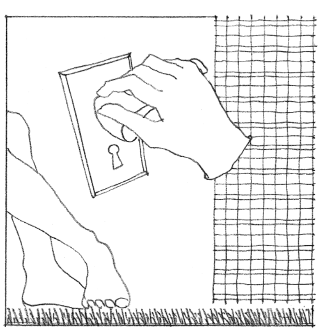
There can also be a dynamic fit as when we enter a building's foyer, walk up a stairway, or move through the rooms and halls of a building.

A third type of fit is how space accommodates our need to maintain appropriate social distances and to control our personal space.

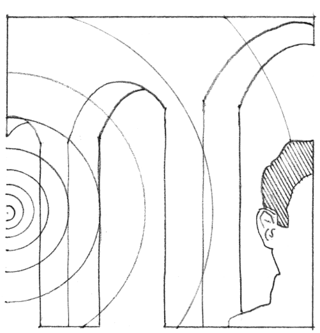
In addition to these physical and psychological dimensions, space also has tactile, auditory, olfactory, and thermal characteristics that influence how we feel and what we do within it.



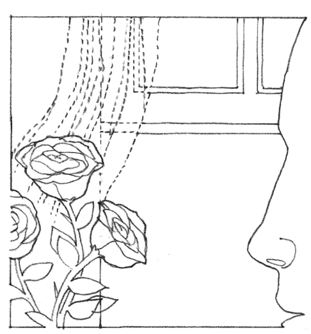
Dynamic fit



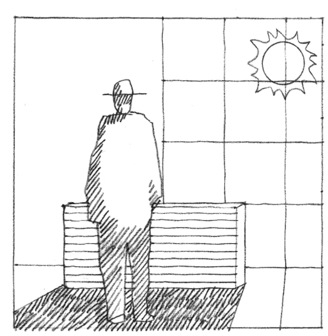
Touch



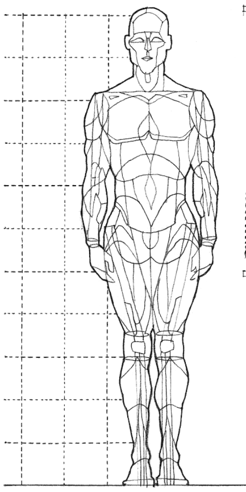
Hearing



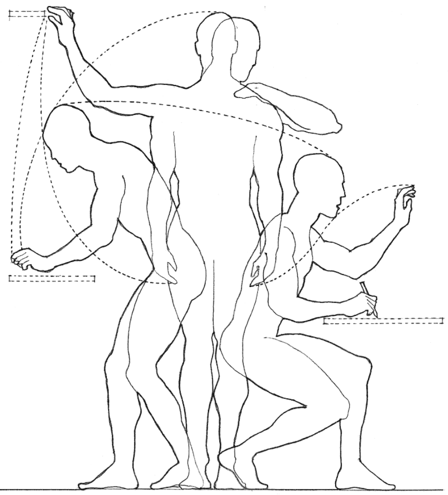
Smell



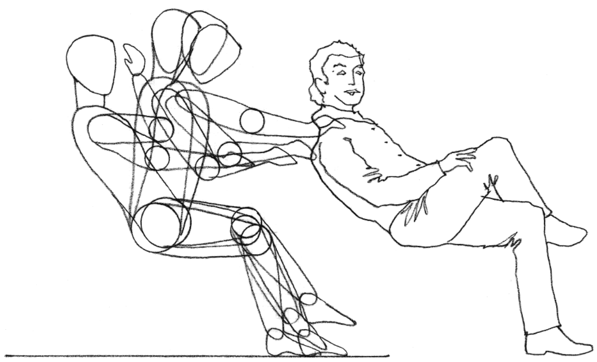
Heat



Structural dimensions



Functional dimensions

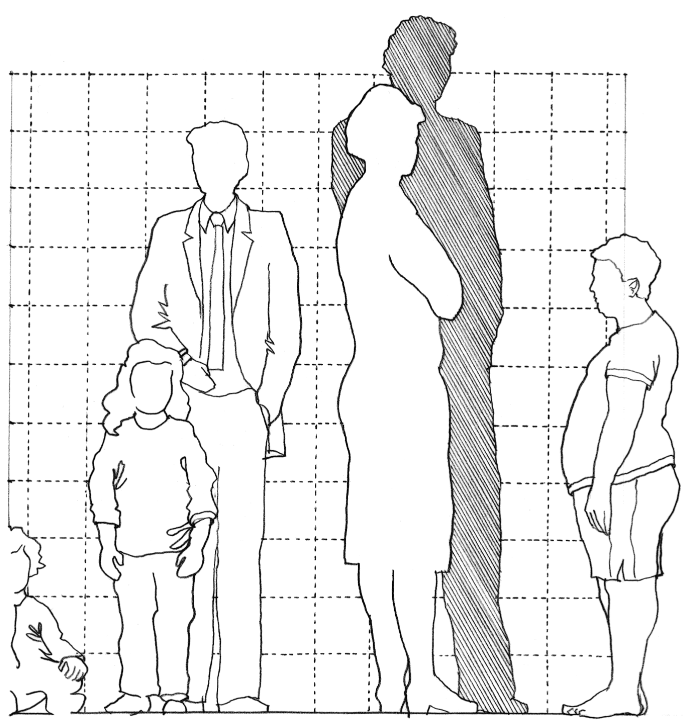


Our body dimensions, and the way we move through and perceive space, are prime determinants of architectural and interior design. In the following section, basic human dimensions are illustrated for standing, sitting, and reaching. Dimensional guidelines are also given for group activities, such as dining or conversing.

There is a difference between the structural dimensions of our bodies and those dimensional requirements that result from the way we reach for something on a shelf, sit down at a table, walk down a set of stairs, or interact with other people. These are functional dimensions that vary according to the nature of the activity engaged in and the social situation.

Always exercise caution when you use any set of dimensional tables or illustrations such as those on the following pages. These are based on typical or average measurements that may have to be modified to satisfy specific user needs. Variations from the norm will always exist as a result of the differences between men and women, among various age and genetic groups, and from one individual to the next.

Most people will experience different physical ranges and abilities as they grow and age, and with changes in weight, height, and physical fitness. These changes over time affect how an interior environment will fit or accommodate the user. *Bariatric* design and design for aging-in-place are two ways that interiors can accommodate these conditions.



Individual variations and abilities

Programming

A prime criterion for judging the success of an interior design is whether it is functional. Function is the most fundamental level of design. We design to improve the functioning of interior spaces and make our tasks and activities within them more convenient, comfortable, and pleasurable. The proper functioning of a design is, of course, directly related to the purposes of those who inhabit and us it, as well as to their physical dimensions and abilities.

To help understand and ultimately to fulfill, the function and purpose of an interior space, it is necessary to analyze carefully the user and activity requirements for that space. The following outline can help the designer program these requirements, translate these needs into forms and patterns, and integrate them into the spatial context.

User Requirements

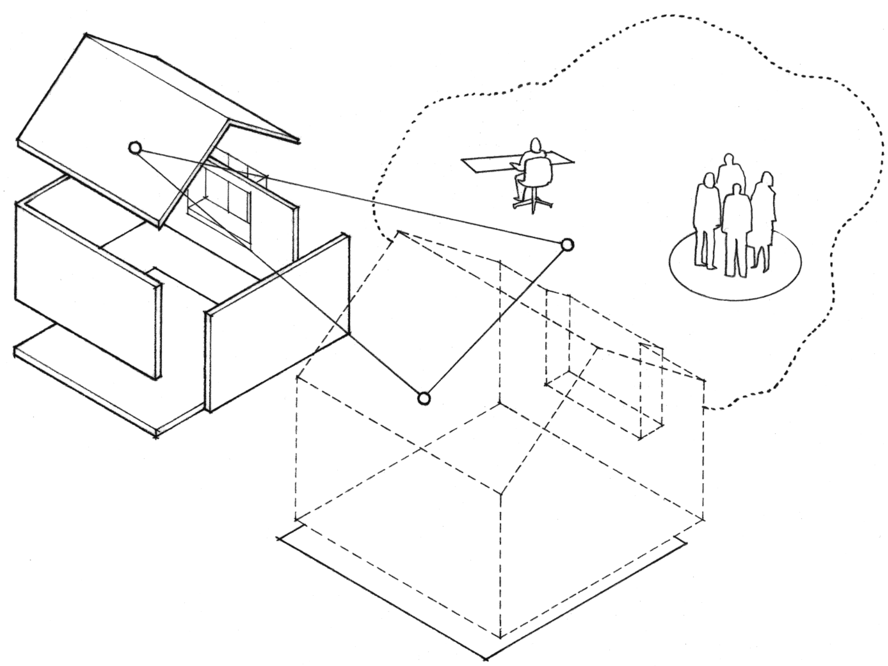
[ ] Identify Users
- Individuals
- User groups
- User characteristics
- Age groups

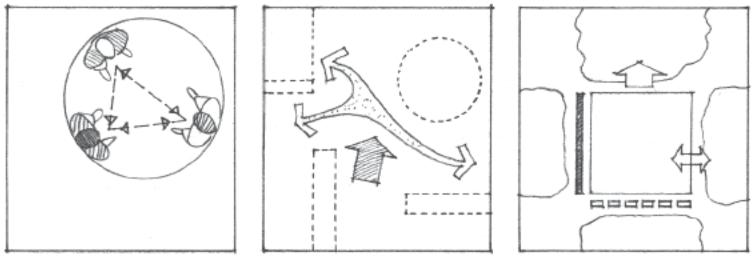
[ ] Identify Needs
- Specific individual needs and abilities
- Group needs and abilities

[ ] Establish Territorial Requirements
- Personal space
- Privacy
- Interaction
- Access
- Security

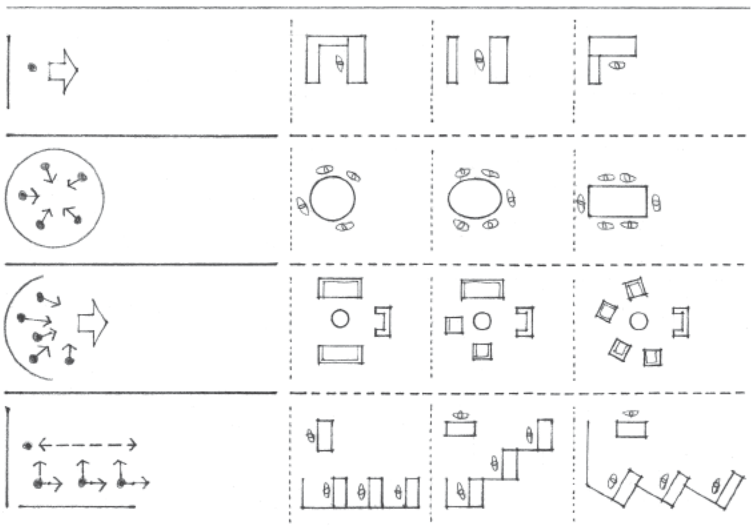
[ ] Determine Preferences
- Favored objects
- Favorite colors
- Special places
- Special interests

[ ] Research Environmental Concerns
- Energy efficiency
- Daylight, views, and fresh air
- Reduce, reuse, recycle
- Water conservation
- Sustainable materials and manufacturing processes
- Low VOC-emitting products
- Decreased waste

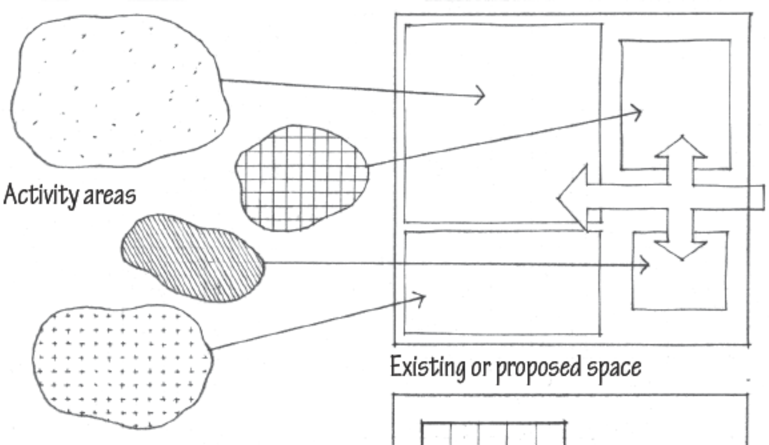




Communication Movement Adjacencies

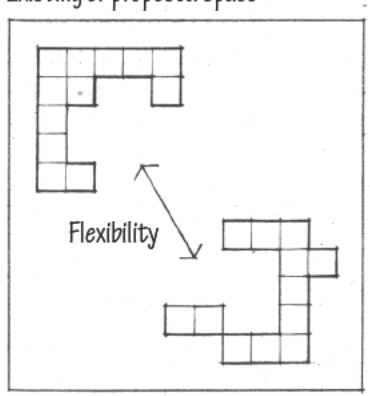


Furniture requirements and arrangements



Activity areas

Existing or proposed space



Activity Requirements

[ ] Identify Primary and Secondary Activities

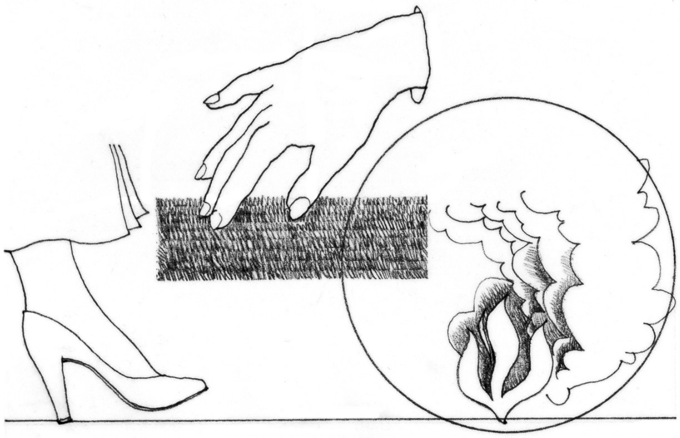
- Name and function of primary activity
- Names and functions of secondary or related activities

[ ] Analyze Nature of the Activities

- Active or passive
- Noisy or quiet
- Public, small group, or private
- Compatibility of activities if space is to be used for more than one activity
- Frequency of use
- Times of day or night use

[ ] Determine requirements

- Privacy and enclosure
- Access
- Accessibility
- Flexibility
- Light
- Acoustic quality
- Security

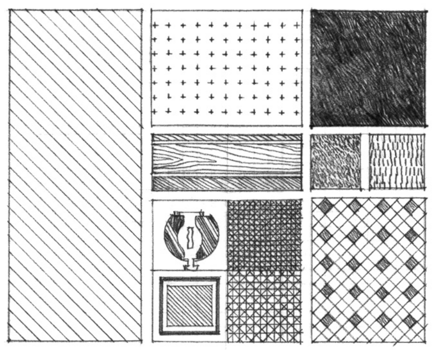


Finish Materials

Finish materials may be an integral part of the architectural assemblies that define an interior space, or they may be added as an additional layer or coating to the constructed walls, ceilings, and floors of a room. In either case, they should be selected with the architectural context in mind. Together with furnishings, finish materials play a significant role in creating the desired atmosphere in an interior space.

Functional Criteria

- Safety, health, and comfort
- Durability in anticipated use
- Ease of cleaning, maintenance, and repair
- Required degree of fire resistance
- Appropriate acoustic properties



Aesthetic Criteria

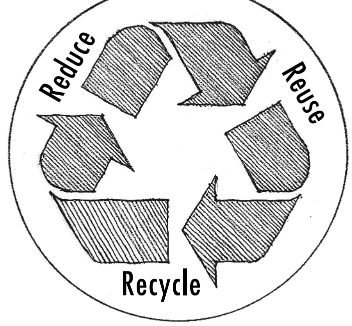
- Color, natural or applied
- Texture
- Pattern

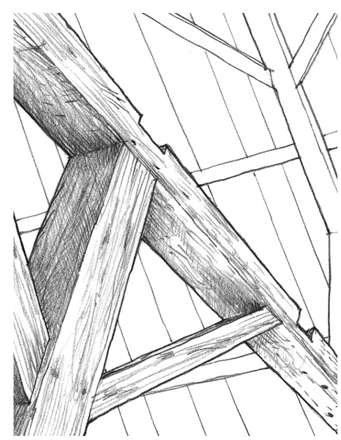
Economic Criteria

- Initial cost of acquisition and installation
- Life-cycle assessment (LCA) of materials and products, including environmental and health impacts from acquisition of raw materials through end-of-use recovery

Sustainable Design Criteria

- Minimization of new materials and reuse of existing materials
- Use of materials with recycled content
- Use of rapidly renewable and certified sustainable materials from local sources
- Use of products from manufacturers who use sustainable processes
- Minimization of waste in construction, installation, and packaging
- Durability and flexibility of use
- Reduction of embodied energy used in processing and shipment





Recycling of timber

FSC

Logo of the Forest Stewardship Council

15 Allied Disciplines:

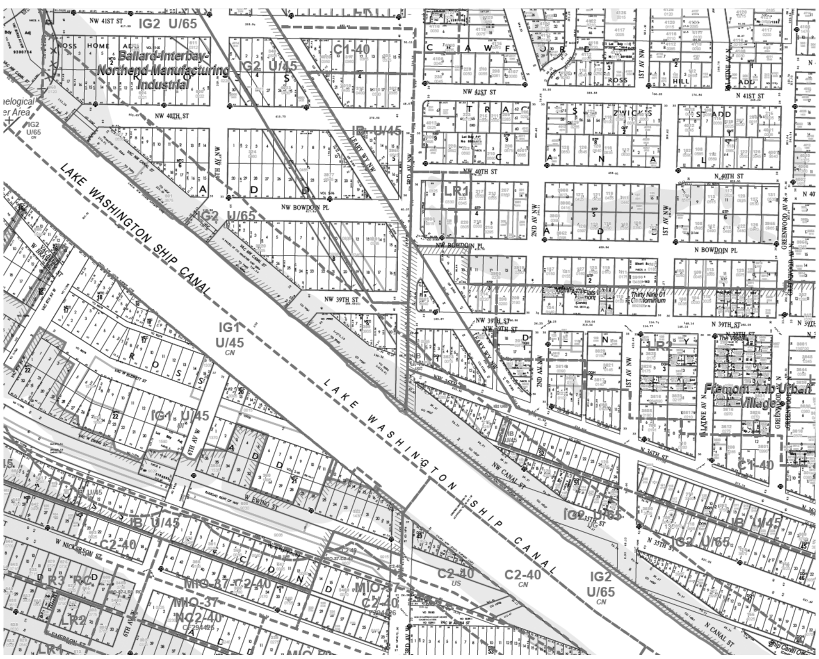
Urbanism

Urban fabric of Mohenjo-Daro, Indus Valley, 2600–1900 BCE

How Is Urban Design or City Planning Related to Architecture?

The profession of architecture has always been interrelated with urban design. Cities are composed of buildings. Each of those buildings contributes to the larger framework of social interaction, program, zoning, and community. These issues are primary concerns for the architect working within an urban context.

It is the task of the city planner to designate open public space, residential areas, industrial areas, commercial areas, and opportunities for civic programs. This type of zoning is, in most cities, committed to law in the form of zoning ordinances or codes. And, as a process it is not different from the way an architect goes about deciding how the various programs of a building will be distributed. However, the relationship between the two disciplines goes deeper than this similarity. Architecture is the principle means by which a city is zoned.



Portion of the zoning map of Seattle, Washington

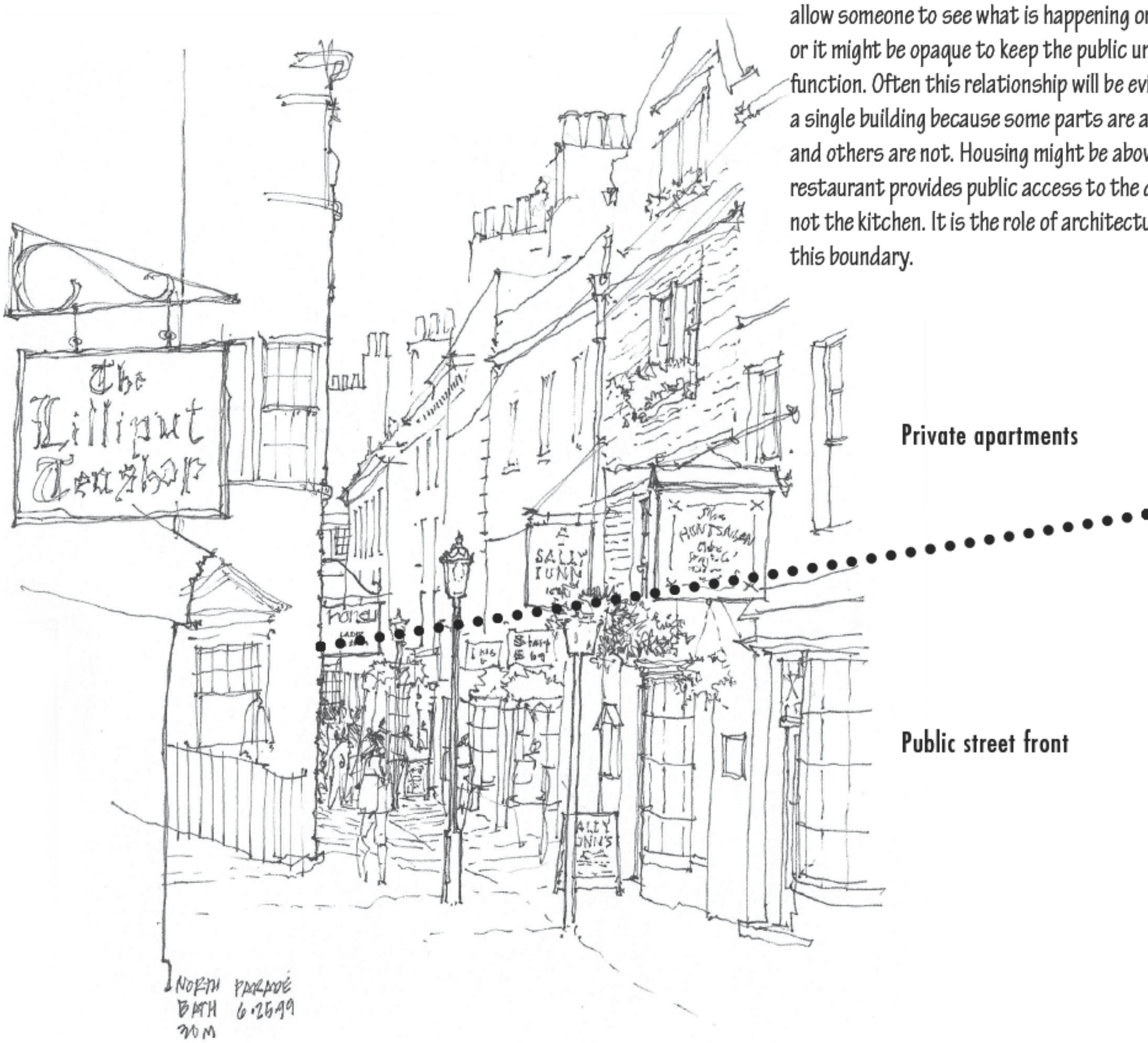
Historically, the architect was the figure responsible for designing the city in addition to the buildings that would compose it. Despite being separated into distinct disciplines today, the architect still shares much of the responsibility for the development of the city. Operating within zoning ordinances of any municipality, the architect's responsibility lies in negotiating the relationship between programs of a city.

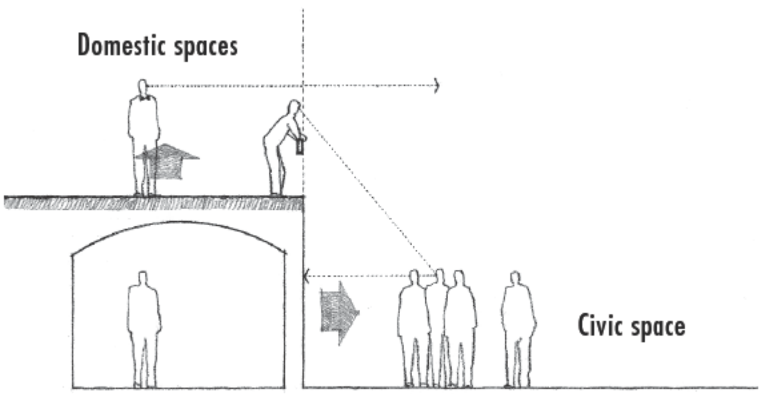
The following are urban relationships established by architecture:

Public vs. Private

A city is dominated by a complex relationship between public and private programs. Public functions are those that are accessible by anyone. They include open public space, shops, restaurants, and cultural institutions. Private programs are those that limit access to a select group of individuals. They include offices, industrial buildings, and housing.

This relationship is primarily defined by the composition of individual buildings. A facade might be transparent to allow someone to see what is happening on the inside, or it might be opaque to keep the public unaware of its function. Often this relationship will be evident within a single building because some parts are accessible and others are not. Housing might be above a store. A restaurant provides public access to the dining room but not the kitchen. It is the role of architecture to define this boundary.

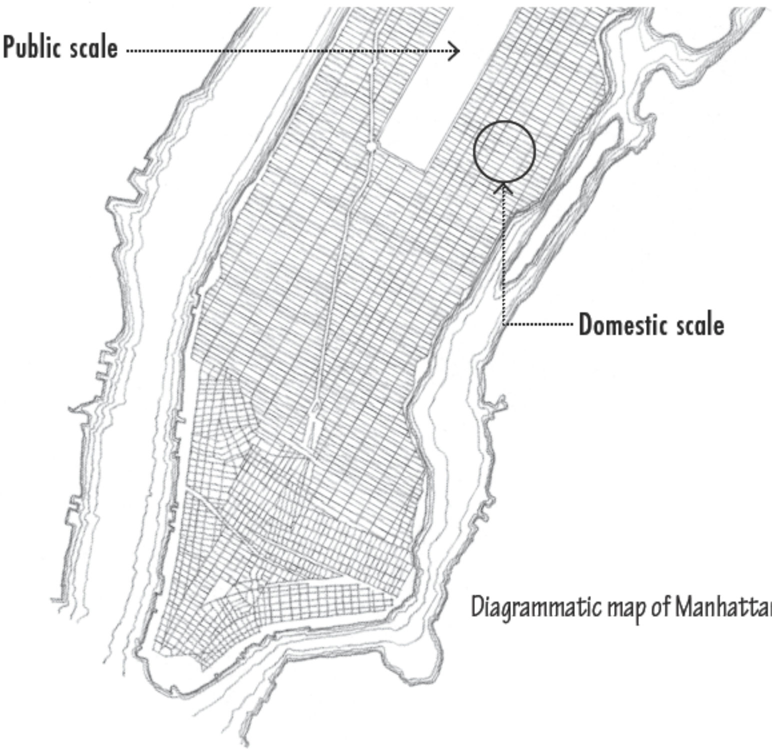




Domestic vs. Civic

Similar to the relationship between public and private is the one between domestic and civic spaces. Domestic spaces are private, residential spaces. Civic spaces are those of the public realm in which social interaction occurs.

An architect must understand this relationship in order to properly distribute programs within a building. At the small scale, a residential building might position a bedroom above the street level so that one might look out a window without risking an invasion of privacy. However, a living room might be placed at street level directly adjacent to the civic environment because it is the location where one might entertain guests. At the large scale, residential buildings might be removed from a large public park or major thoroughfare in favor of smaller urban gardens and streets.



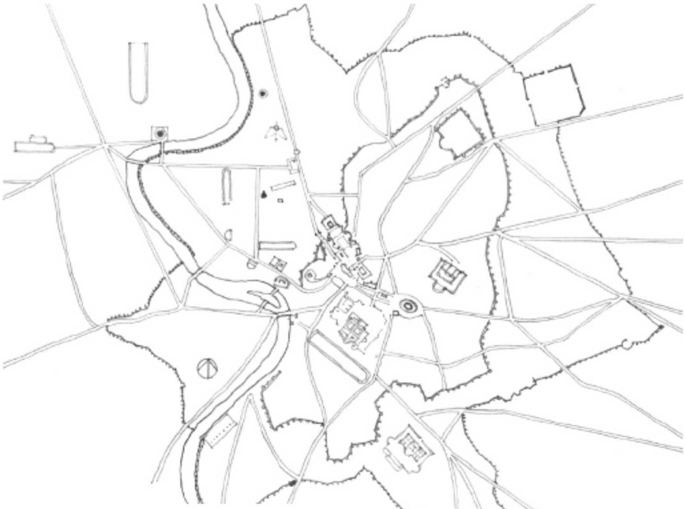
Diagrammatic map of Manhattan, New York City

Social Interaction

The relationships listed above speak to degrees of social interaction. Architecture in a city plays a major role in defining the way people interact with one another. It provides space for a conversation to take place, or a window through which one can observe people on the street.

In this chapter, the city will be addressed. The chapter will present urban typologies and different ways in which architecture influences the growth and development of the urban condition. This chapter will also address the social context of a city and architecture's role in a community.

Urban Taxonomy



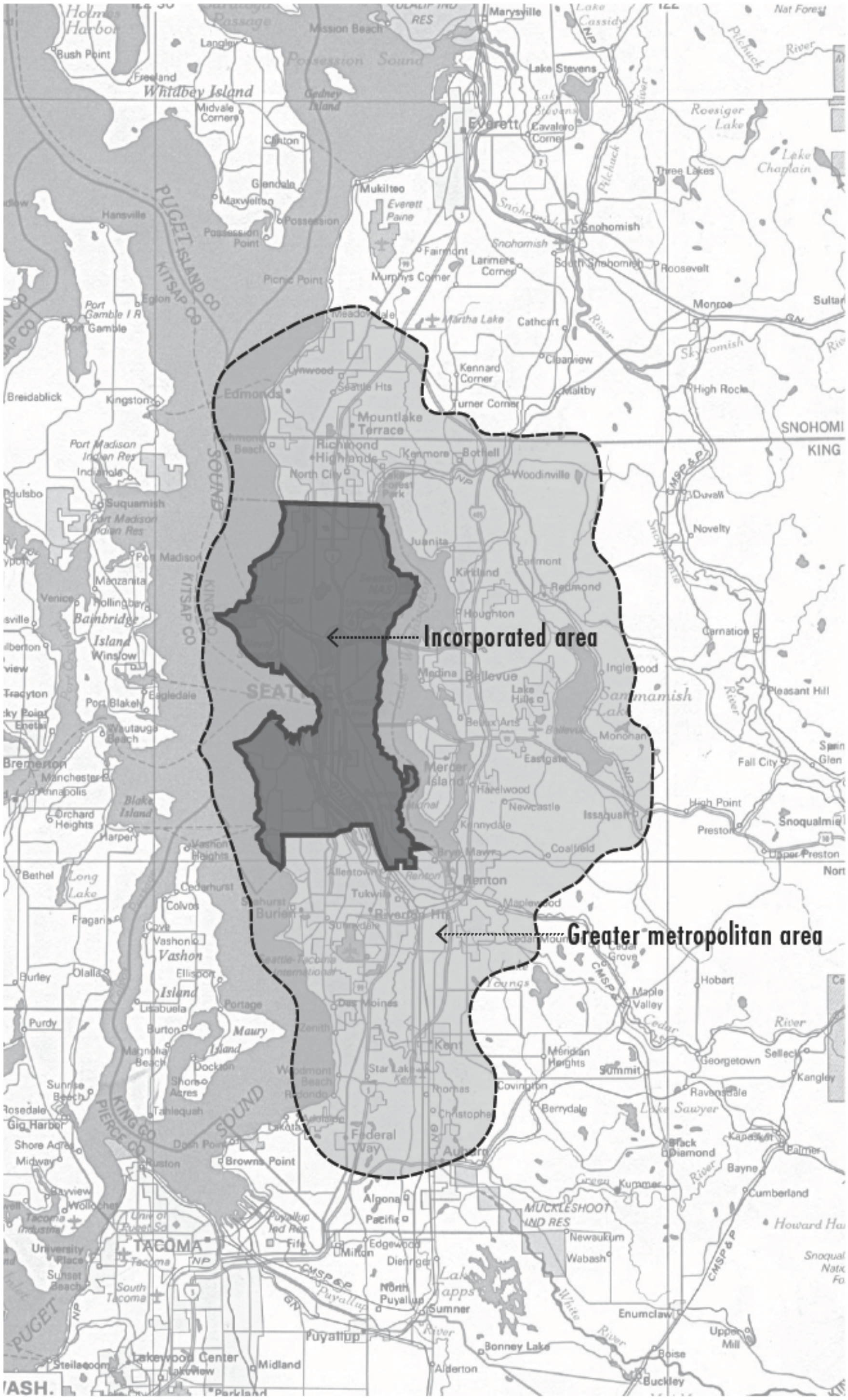
Plan of Imperial Rome ca. 1 CE

What is a city really? Density, a collection of structures, street grid, infrastructure, and civic institutions all characterize a city. What defines a city, however, is more fundamental. The city is the pinnacle of human settlement. It is a point where people gather, dwell, and interact for mutual benefit. A city can be understood as collective identity of the people who live there established through their traditions, social practices, and manner of living.

To the architect, these aspects of community influence the way people will occupy and use any building designed in a place. People interact with one another and use space differently from one place to the next. These differences should be considered during the design process to ensure that a building successfully meets the needs it was intended to address.

Typically, when we look at a map of a city, the first thing we see is the street grid. However, consider that a city is not a composition of streets, but rather a collection of structures. This shift in perception allows us to understand the city in a slightly different way. Each building that is erected in a city is intended to meet a need of the people of that place. Architecture, therefore, is a fundamental aspect of urban development. It becomes one of the architect's tasks to identify needs of a place and satisfy them with design. This variability in ways that a city can develop leads to a variety of types; from small to large, less dense to more dense.

In these figure-grounds of Washington, D.C., the streets emerge as spaces between buildings as opposed to being delineated simply by linework.



Map of Seattle, Washington, indicating both its incorporated area and the greater metropolitan area.

A City and Its Surroundings

Legal definitions of urban environments based upon population vary widely from country to country. In the United States, these definitions even vary from one state to another. For this reason, this section is going to present only general characteristics of these types.

To define the urban environment based on population, one must understand its relationship to its surrounding area of influence. Urban conditions serve as a focal point for a surrounding area. In larger cities, this region is referred to as the greater metropolitan area. Even in smaller settlements, however, such as towns, there is a surrounding territory whose population depends on the amenities provided by the urban center.

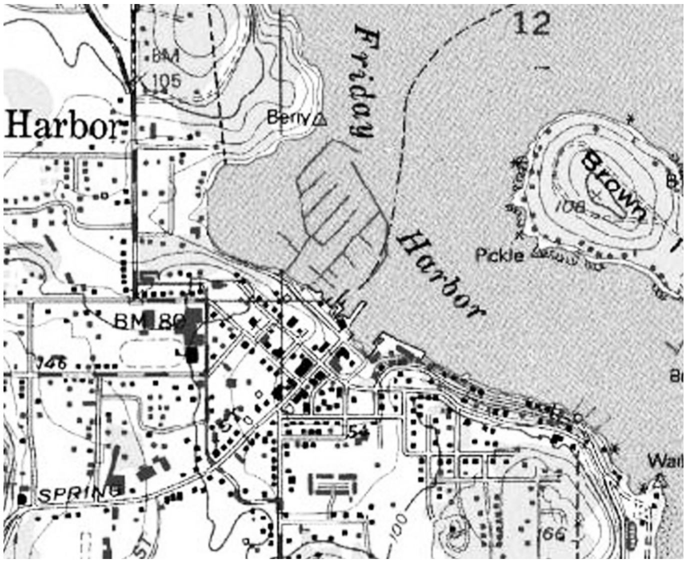
These surrounding regions consist of populations living in communities or even smaller settlements that are often not legally considered a part of the city. Regardless, people in those areas will often identify themselves as being from the primary town or city. They will take advantage of it for commerce and social events. These focal point urban environments also provide civic amenities that might not be found in the periphery, such as courthouses, libraries, or museums.

It is for this reason that urban populations are frequently calculated in two ways. One is the populace living within the incorporated confines of a town or city. The other is the populace of the greater metropolitan area.

City Typology Based on the Size of a Population

Town, Village, Borough

These are typically urban typologies that are smaller in both size and population than a city. They also influence a smaller surrounding area than their larger counterparts. At the center, there is a density of structures and people characteristic of an urban condition, but it is tightly confined and usually organized around a small number of primary streets, or intersections. Easy access to primary streets enables the outlying populace to have efficient access to urban amenities, such as commerce and social events. This scale of urban environment tends to provide limited access to major civic amenities such as large-scale financial institutions or government agencies.



Map of Friday Harbor, Washington

Saturday market in Sarlat, Dordogne, France

City

The city is a large urban focal point with a greater metropolitan area composed of a relatively large population, many living in unincorporated townships. It is typically composed of a network of blocks arranged within a street grid. Within blocks, buildings will often be grouped according to program and size. The density of the city usually demands an increased presence of mixed-use architecture, where multiple programs are housed within a single building.

The city has a distribution of residential programs to serve its large population. An important facet of urban life is the neighborhood. The city relies on not just the commerce-oriented center, but also a well-connected, suburban environment. A successful city will usually be one that has developed an interdependent relationship between its civic core and domestic neighborhoods. The advantages of living in, or with easy access to, a city is that it provides its residents with access to major civic institutions for culture, education, and governance. There is also a greater diversity of commerce ranging from small business to corporate headquarters and major financial institutions.

Map of Seattle, Washington, showing the Central Business District (CBD) in relation to its many neighborhoods.

Street scene in Hong Kong, China

Metropolis

The metropolis is a city that has grown in size, population, and density, to such an extent it can no longer be considered in the same category with its smaller counterparts. It supports a massive population that is typically very diverse in terms of socioeconomic demographics, culture, ethnicity, and nationality. A metropolis is home to major national and international corporations, financial institutions, and government agencies in addition to the smaller-scale urban amenities offered by any city.

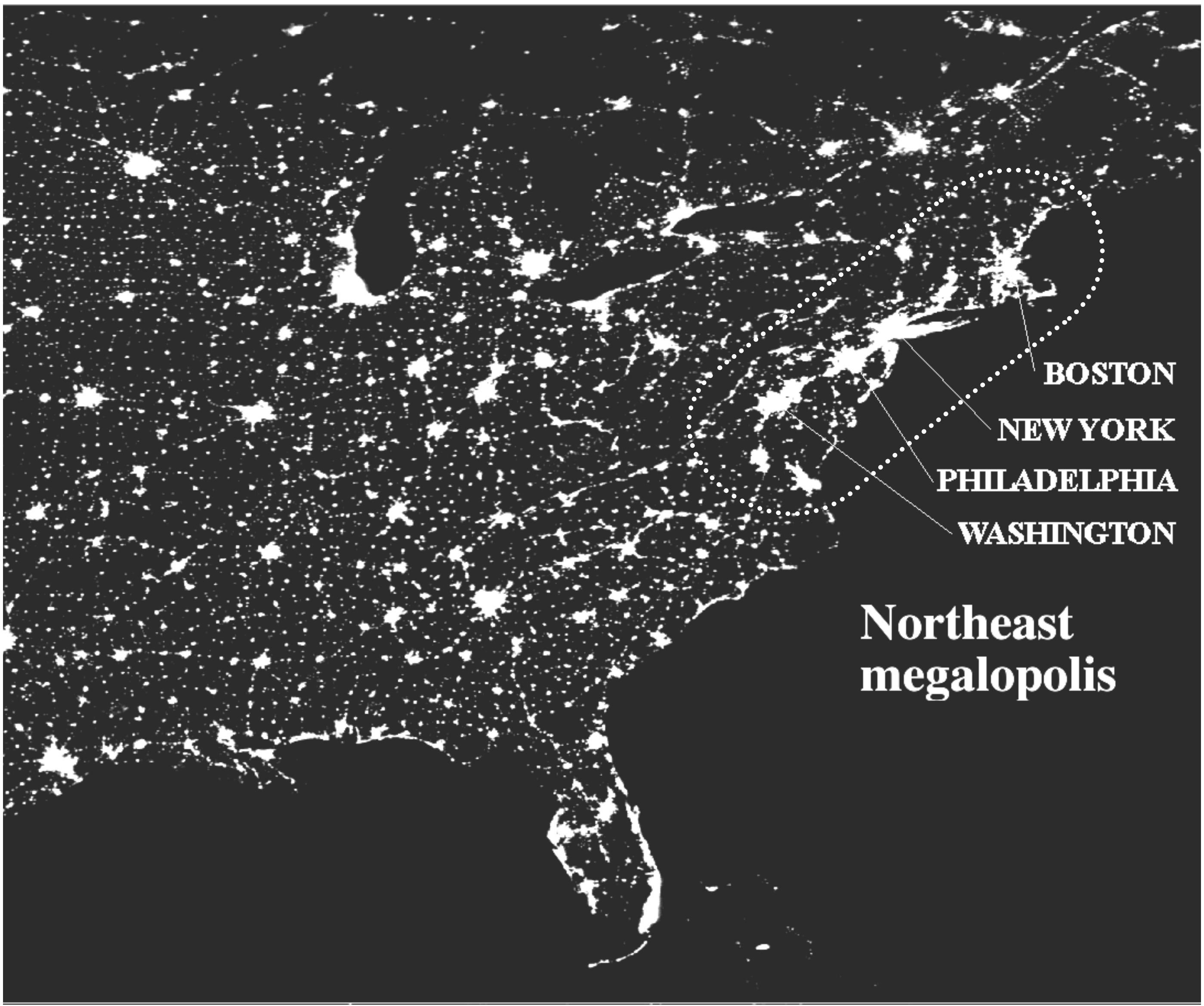
The metropolis is an international city that supports a diverse population of both residents and visitors. It can also be representative of a nation in that it will be a common host to foreign officials and dignitaries.

Street scene in Shanghai, China

Photo of London, United Kingdom, taken from the International Space Station (ISS) during Expedition 23 on May 22, 2010.

Megalopolis

A megalopolis is a grouping of cities that have expanded to the point where their peripheries have overlapped causing a degree of integration between them. These typologies often share certain infrastructural systems such as mass transit. They also promote a degree of cultural overlap, whereby communities develop centered on commuting from one city to another to serve both business and family priorities. Populations also sometimes begin to share customs and traditions as these practices cross-pollinate from various units of the megalopolis to the others.



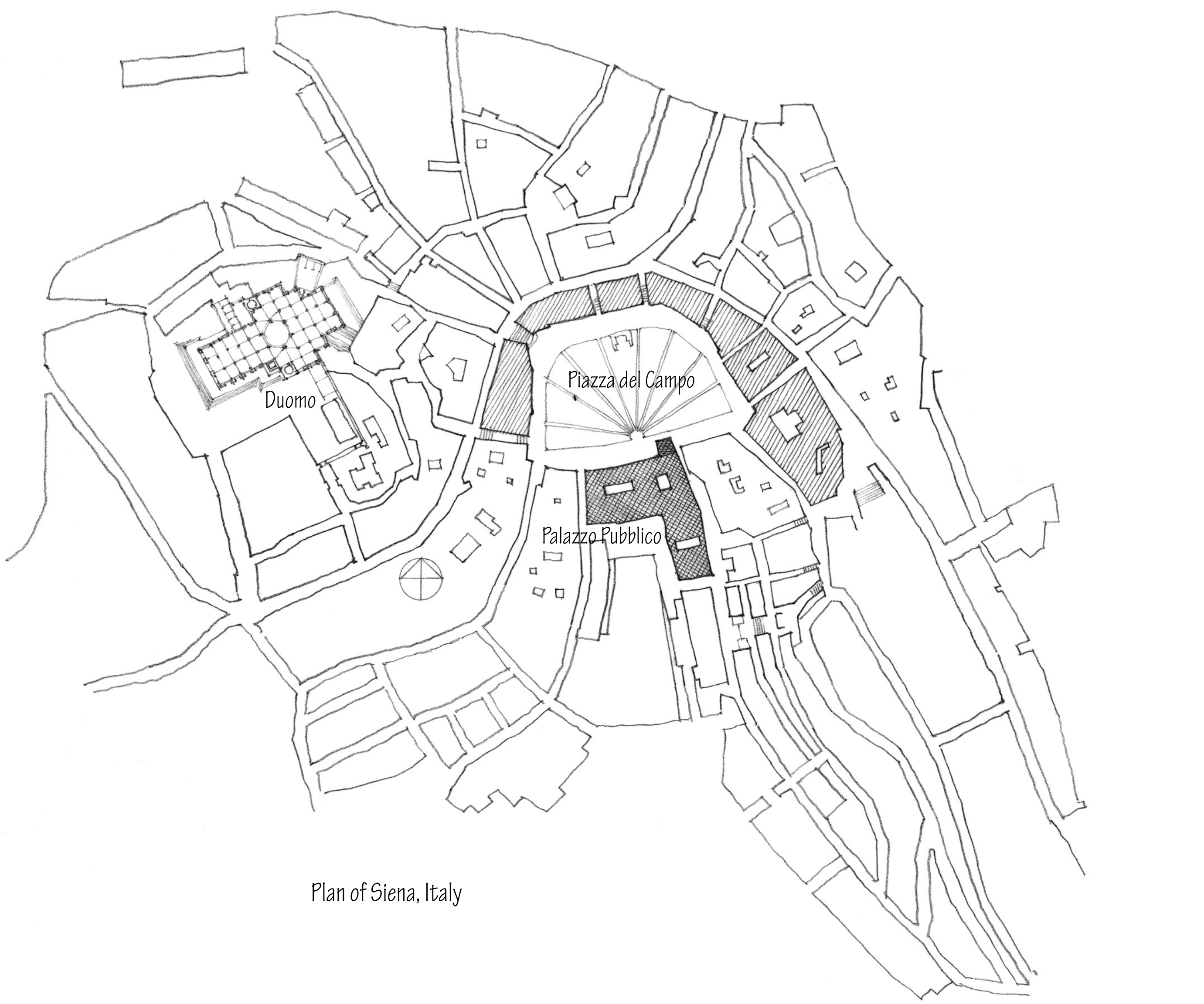
NASA photo of the northeast U.S. megalopolis comprising New York, Boston, New Jersey, Washington, D.C., Baltimore, Philadelphia, Hartford, Richmond, and Norfolk, with a total population of over 50 million people.

Urban Environment Typology Based on the Density of Population

Urban

Urban environments are characterized by high density of both population and buildings. In order to maintain this density, the urban typology relies on overlapping systems.

- Mixed-use buildings provide the opportunity for multiple types of programs to occupy the same area.
- Multiple opportunities for transportation (mass transit, vehicular, pedestrian, etc.) allow for efficient movement of people, goods, and services.
- Taller buildings permit more usable square footage per unit area.
- Density permits access to any good or service within walking distance of any particular location.



Plan of Siena, Italy

Suburban

A suburban environment is less dense than the urban described in the previous section. It tends to have a greater proportion of residential and domestic programs compared to the urban environment. Its main characteristic is an interdependent relationship with an urban center—"sub-urban." Despite its primarily residential nature, the suburban environment still relies on a diversity of programs to provide its communities with various resources.

- Primarily Residential
- Less dense than the urban, but still maintains small lot sizes, or even shared party walls to accommodate many residents.
- Some mixed use zoning for small-scale commerce, civic amenities, and infrastructure to support residents of the neighborhood.
- Easy access to an urban center—most residents will rely on the urban center for jobs and other resources not found in the suburbs.

Typical suburban density with relatively small residential lots interrupted by open space and a few larger buildings.

Rural

Rural environments tend to be agrarian. They are much less dense than either the urban or suburban environments. Here, residences are typically single family and dispersed across a very large area. Typically, there is still reliance upon a small urban center (a town or shops along a main street) for access to necessary goods and services.

- Communities are composed of a small population of individuals.
- Almost no overlap in program or transit except in the central town or other focal point
- Small urban centers provide minimal, necessary commerce and civic institutions (local government, post office, etc.)
- Heavy reliance on farming, resource production, and sometimes industry

Typical dispersed nature of buildings in an agricultural community

Exurban

Often referred to as "suburban sprawl" the exurban environment is one where residential programs have little or no connection to an urban center and instead exist as semi-autonomous units. They are generated as the suburban typology expands beyond the area of influence of its urban center. In the place of urban social structures and commerce, the exurban environment relies on shopping centers that cater to commercial chains in order to provide the necessary social interaction as well as the goods and services needed to maintain a particular lifestyle.

- Very low density of population relative to resources produced (not as low as a rural environment, but also not as productive)
- Characterized by zoning that separates programs rather than relying on mixed use zoning
- The low density makes vehicular traffic a necessity, making it the nearly exclusive for of transportation.

Exurban development often occurs in rural communities.

Make-Up of a City

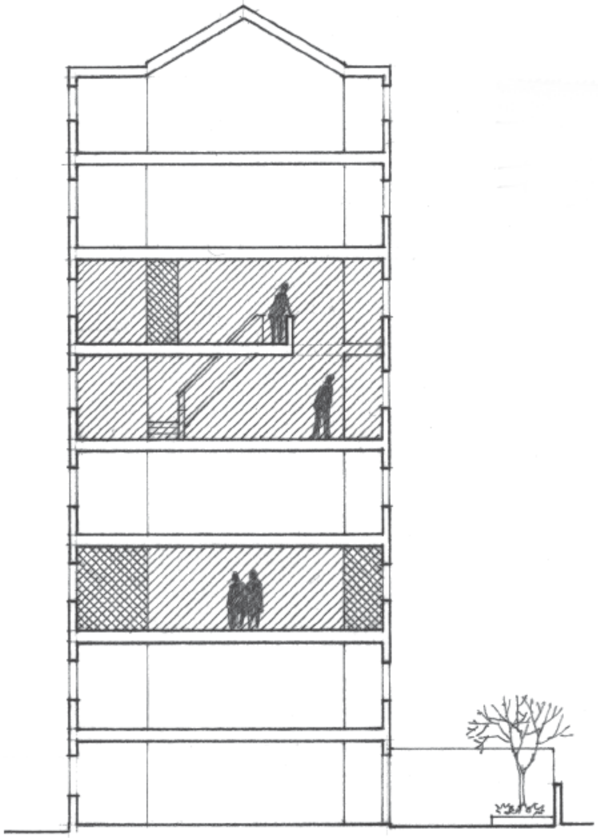
A city is a diverse place. It is composed of many different groups of people. It must offer many amenities in the form of services, infrastructure, and cultural institutions. It must also produce a range of resources through various industries. This inevitably results in a diversity of architectural design solutions in order to meet the needs of a typical urban population.

The diversity of city functions can be grouped into four categories:

- Domestic: Private residence and individual ownership
- Civic: The public realm, government institutions, and cultural institutions
- Commercial: Access to goods and services
- Corporate: Management and administration of companies within the city as well as those that extend beyond its borders
- Industrial: Production of resources

Walter Burley Griffin's plan for Canberra, Australia, 1912

Domestic



Domesticity is a fundamental component of a city. Domestic functions are any of those that pertain to residence or individual ownership. This urban function speaks to one specific need—to dwell. The act of dwelling changes form depending on the urban environment within which it exists. Dwelling in a major metropolitan urban center might be in the form of an apartment in high-rise building, where dwelling in an urban suburb can take the form of a row house or single-family residence.

Amenities that support the domestic function also change along with its form. The need for transportation might come in the form of mass transit or ownership of a car. Proximity of the domestic unit to the urban center also affects the distribution of access to goods and services necessary to support the standard of living expected by the population of a neighborhood.

Domestic programs provide support to the other functions of the city. It provides housing for employees of businesses that make a city economically viable; it also provides those businesses with patrons. This relatively simple reality of urban domesticity is made more complex when considering the placement of domestic units relative to other urban programs. Providing efficient access of a population to opportunities for commerce and employment is a necessary consideration of urban design.

Examples of domestic or residential architecture include:
- Apartment buildings
- Condominiums
- Row houses
- Single-family, detached houses
- Hotels

Civic

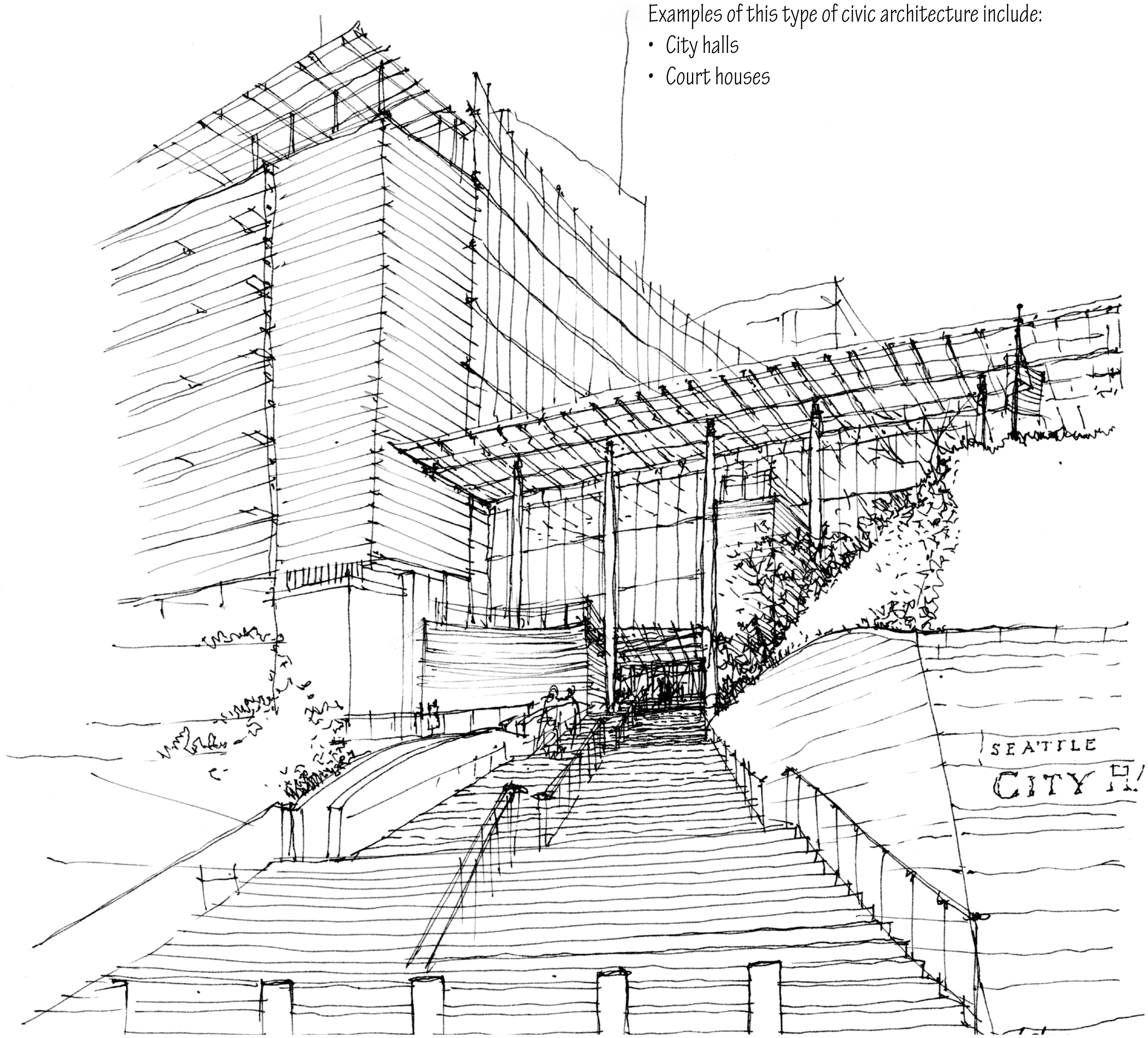
Civic programs are those dedicated to the common good of the people of the city. More specifically, civic programs are those that pertain to government, public service, public welfare, culture, and the common public realm.

Civic: Government

Any government agency in a city contributes to the civic environment. This includes the structures that house legislative bodies, executives, and the courts. This type of civic architecture also houses various administrative functions from tax collection to planning and zoning departments.

Examples of this type of civic architecture include:

- City halls
- Court houses

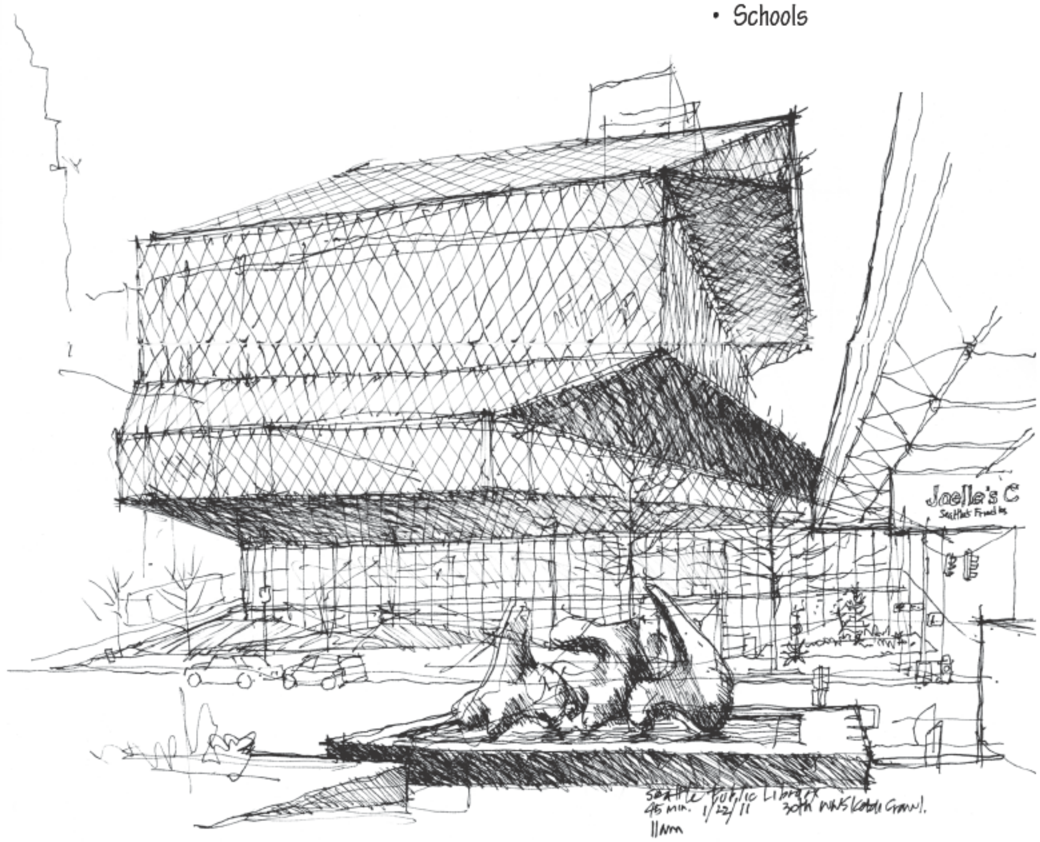


Seattle City Hall, 2005, Bohlin Cywinski Jackson/Bassetti Architects

Civic: Public Services

A major component that ensures the success of a city is the number of civic amenities that it offers. These usually come in the form of access to public services. This includes the structures that house goods or services provided by the city for the common good of its citizens.

Examples of this type of civic architecture include:
- Public libraries
- Community centers
- Schools



Central Public Library, Seattle, Washington, 2004, Rem Koolhaas & Joshua Prince-Ramus of OMA/LMN Architects

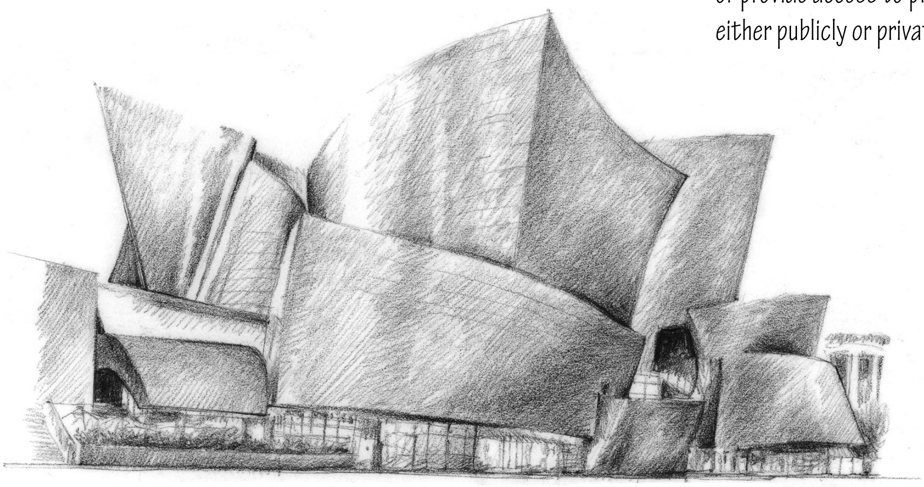
Civic: Public Safety

An important factor that determines the success of a city is the safety of its citizens. To that end, there are a variety of services offered both publicly and privately that safeguard a populations physical well-being. This type of architecture houses programs such as law enforcement and health care.

Examples of this type of civic architecture include:
- Hospitals
- Police stations
- Fire stations
- Emergency medical services

Civic: Cultural Institutions

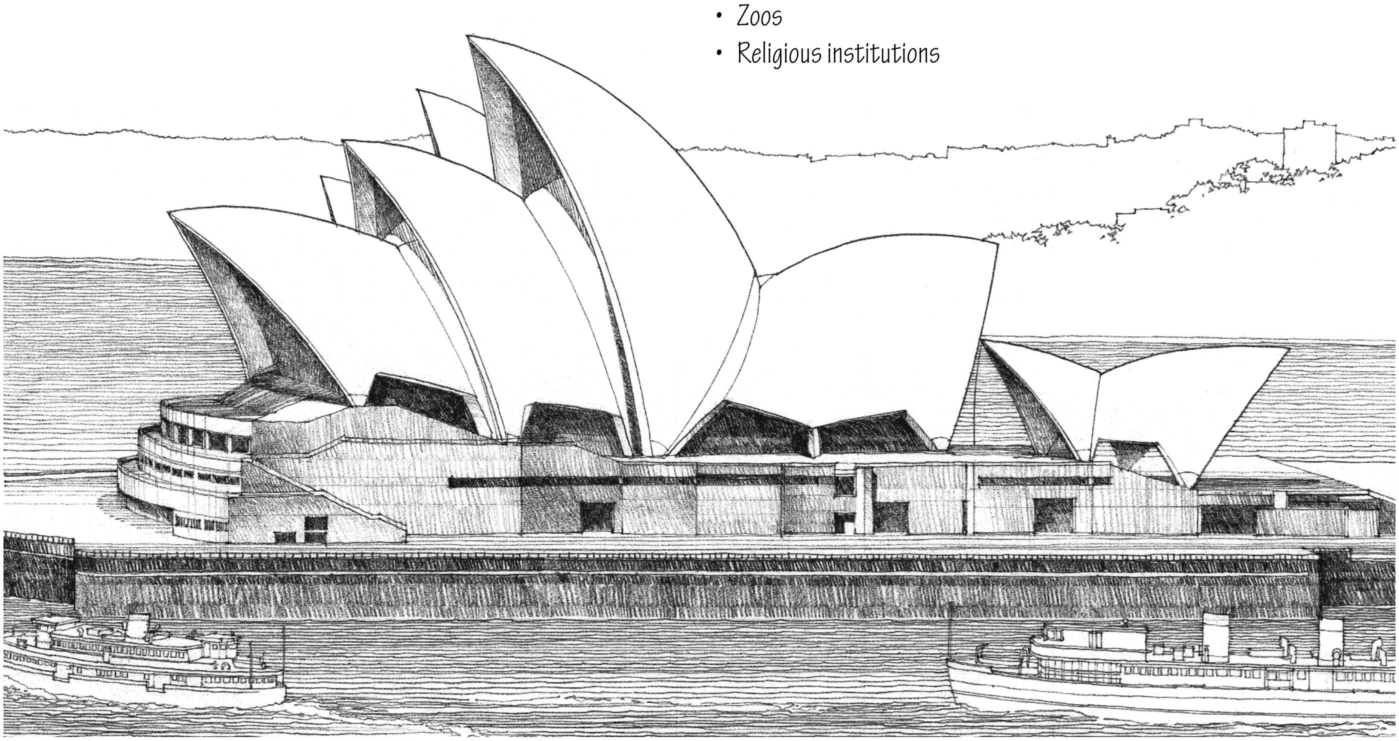
The long-term success of a city depends heavily on continually attracting residents to fuel growth and visitors to bolster the economy. This largely depends on access to civic amenities in the form of cultural institutions. This includes the structures that house cultural artifacts, performance, or provide access to place specific information. These institutions can be either publicly or privately funded; often they are both.



Walt Disney Concert Hall, Los Angeles, 1999–2003, Frank Gehry

Examples of this type of architecture include:

- Museums
- Galleries
- Recital halls
- Playhouses
- Historical centers
- Zoos
- Religious institutions



Sydney Opera House, Sydney, Australia, completed 1973, Jørn Utzon

Civic: Public Space

The broadest category of civic architecture is that which deals with the most fundamental of public civic amenities. These are the public aspects of a city that focus on the common public environment. This includes structures that provide opportunities for casual social interaction, facilitate transit, open space, and recreation. These services and the structures that house them can be privately funded and operated, but they are usually the responsibility of the city.

Examples of this type of architecture include:

- Sidewalk and streetscape
- Public open space
- Event space
- Parks
- Bus stops and subway stations

Campo de' Fiori, Rome, Italy

Commercial

Urban environments thrive on commerce. Commerce drives the urban economy, and availability of diverse goods and services attracts residents to spur growth. A city is home to a very wide range of commercial architecture. It spans a range of sizes from very small local shops to very large chain stores. It also spans a wide range of different goods, providing more selection than less dense areas. The population of a city also makes specialty stores viable because the critical mass of population provides enough people interested in whatever specialty goods or services they might offer. Because of this, the residents of a city often have access to goods or services that can't be found outside of the dense urban environment.

Apple Store, Fifth Avenue, New York City, 2006, Bohlin Cywinski Jackson. Glass cube redesigned 2011

Distributing commercial activities is an important facet of urban planning and design. Different regions of a city demand access to different goods and services. Primarily residential neighborhoods require access to goods and services to support everyday activities such as groceries and home goods. Specialty retailers might be better positioned in a more dense, primarily business environment of a downtown. These are goods and services that most people won't require on a daily basis, so travel to and from this type of commerce is more accepted.

Examples of commercial architecture include:

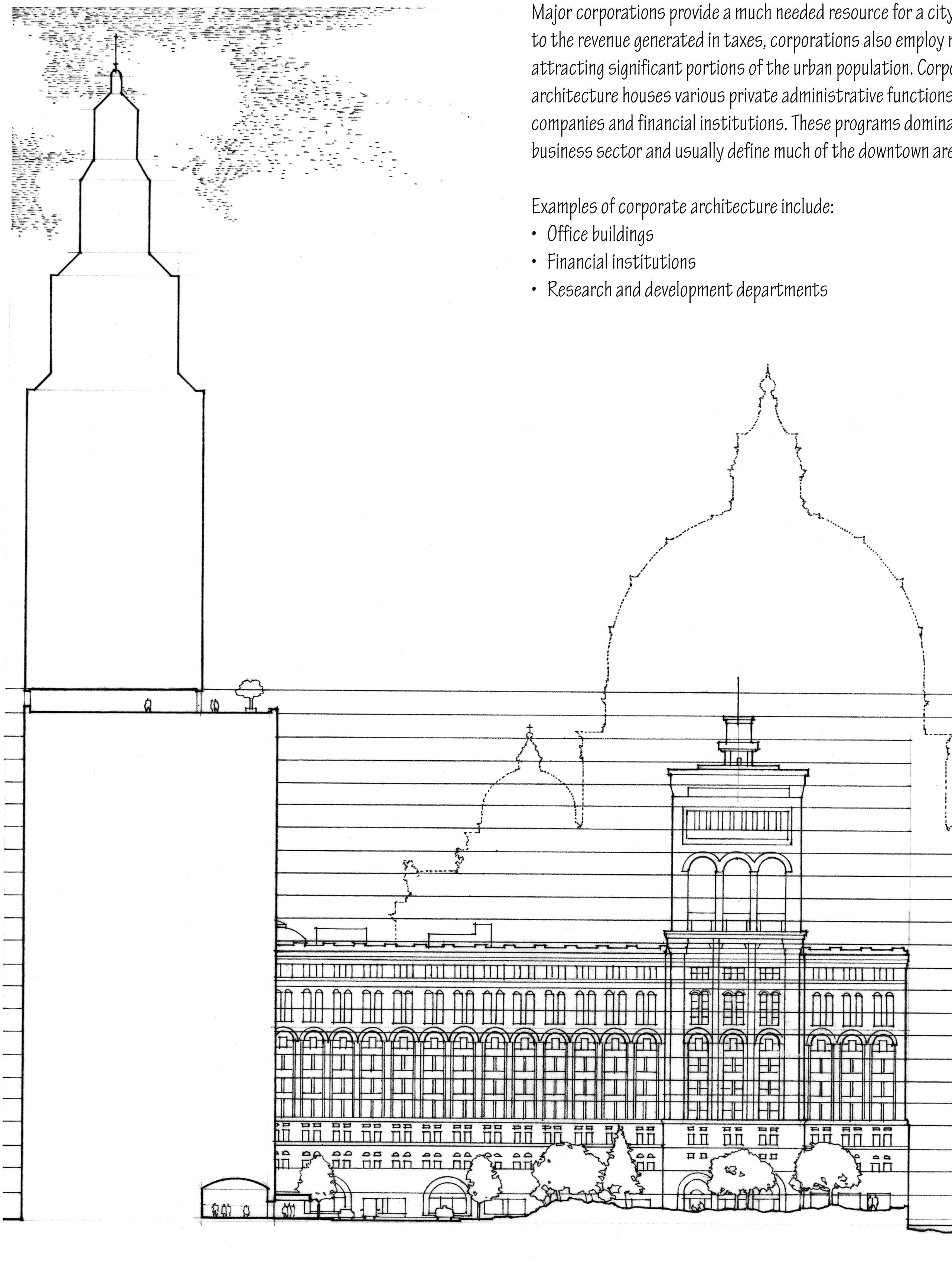
- Shops
- Boutiques
- Large-scale stores
- Malls, retail chains, and department stores
- Restaurants
- Grocery stores
- Convenience stores

Corporate

Major corporations provide a much needed resource for a city. In addition to the revenue generated in taxes, corporations also employ many people attracting significant portions of the urban population. Corporate architecture houses various private administrative functions of large companies and financial institutions. These programs dominate a city's business sector and usually define much of the downtown area.

Examples of corporate architecture include:

- Office buildings
- Financial institutions
- Research and development departments

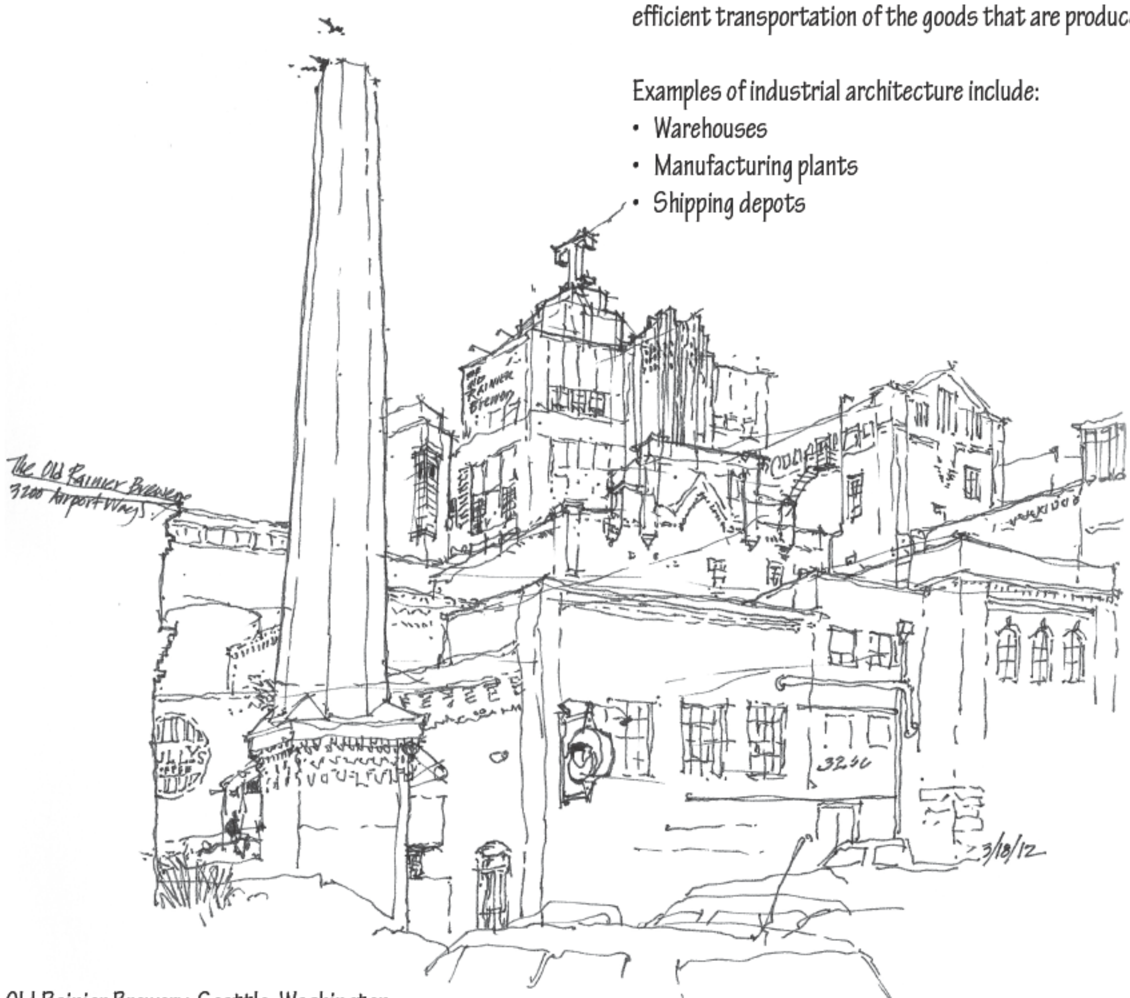


Industrial

Industry in a city is also vital to its success, but it is difficult to integrate into a dense urban fabric. Industry includes any shipping, processing, or manufacturing of goods. These industries supply many jobs and, therefore, attract population to an urban center. They also produce resources in the forms of goods to be sold that drive a portion of an urban economy.

Distributing industrial programs in an urban environment is difficult because of the space and land requirements of such programs. Urban land is very valuable because of the amount of program it can house, and industrial buildings tend to require expansive amounts of space without the ability to expand upward. Because of this, industrial sectors of a city tend to be significantly less dense than commercial or residential areas. Lack of density makes getting from one building to another more difficult in that it increases travel time and is serviced by fewer transportation methods. Additionally, noise and fumes that result from production make these areas less desirable for much of the urban population. These factors usually cause industrial areas to be removed from the center and isolated from any residential sector of a city. They are also usually located within a close proximity to shipping resources such as train stations or boat yards for efficient transportation of the goods that are produced.

Examples of industrial architecture include:
- Warehouses
- Manufacturing plants
- Shipping depots



Old Rainier Brewery, Seattle, Washington

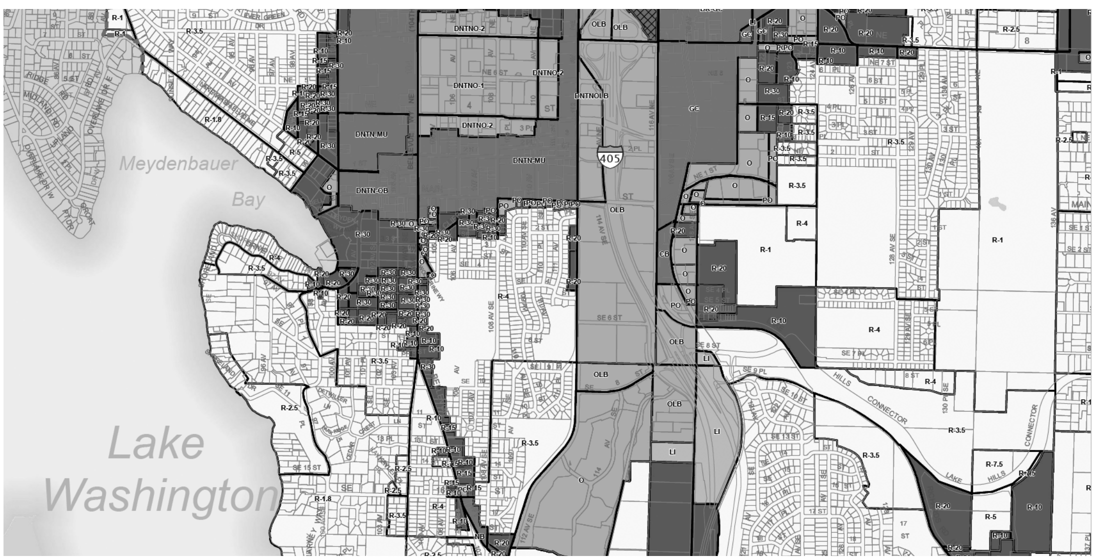
Zoning

One of the ways that urban development is controlled is through municipal zoning ordinances. Architecture designed in a city is subject to them. They govern characteristics of architectural design that directly affect the urban environment. They are intended to define strategies for a city's growth and development. From one municipality to the next, zoning regulations vary greatly in both strictness and the issues they address. This section provides some general information regarding ways zoning might impact architectural design.

Zoning ordinances provide a set of limitations within which an architect can work through the design process. They regulate many characteristics for the way a building interacts with those around it, the kinds of activities it houses, general characteristics of form or even ways a new design should contribute to a historic fabric. When well conceived and interpreted, they can be a guideline for innovation rather than a hindrance to design. Most municipalities grant permission to alter or disregard some of the regulations within their zoning ordinances when special circumstances warrant it.

Some aspects of architecture that are regulated by zoning:

- Land use
- Site and urban density
- Form and appearance
- Historic preservation



Portion of the zoning map of Bellevue, Washington

Land Use

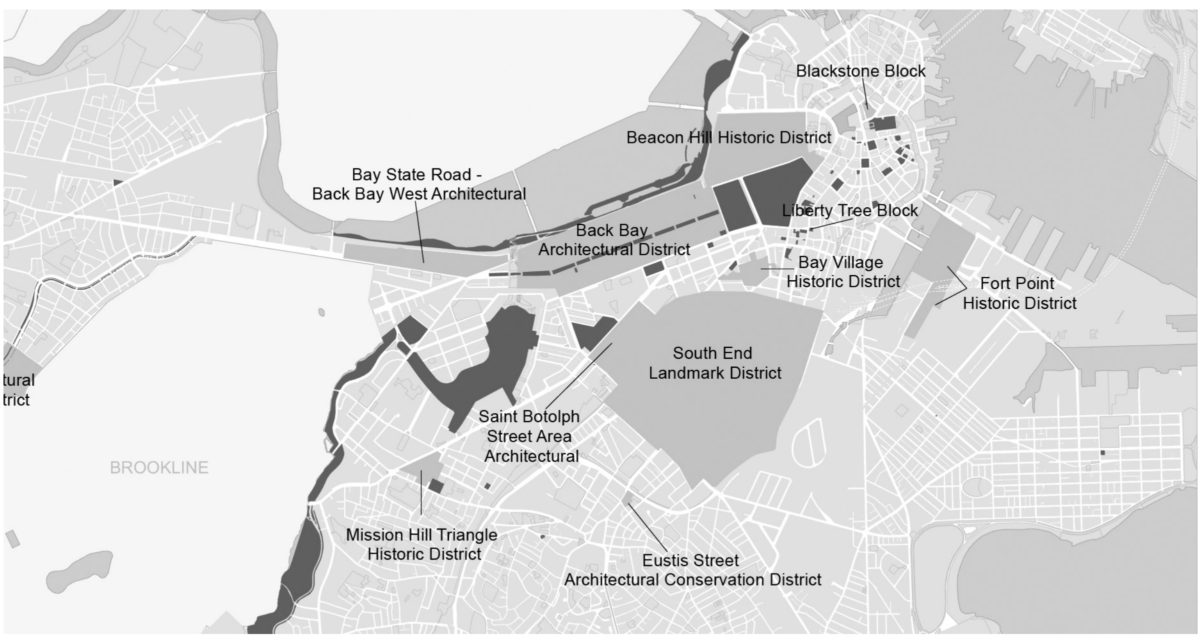
Some cities employ a strategy of dividing the urban landscape into regions based upon use, such as residential, commercial, or industrial. This determines what types of buildings can be designed in any given location. It is one way in which a city protects the interests of its population. As an example, a land use regulation might ensure that a factory will not be constructed in the midst of a residential neighborhood. This provides some safeguard for property value as well as confidence on the part of the resident that their sense of place and community can be preserved.

Site and Urban Density

Cities might also control the sizes of new buildings in certain areas, or the way one is positioned on its site. For example, setback requirements determine how far a new building must be from its property lines. Property setbacks determine urban density by controlling how many structures can be placed in an area. They also determine the proximity of buildings to a street giving local governments some influence over the character of their streetscapes.

Form and Appearance

Some municipalities want to promote a certain image for the way a place is experienced. To do this, there are rules governing the appearance of buildings; anything from color, to material, to signage might be regulated to maintain certain characteristics of a place. These ordinances are intended to preserve desirable aspects of the city that will retain or even attract new population.

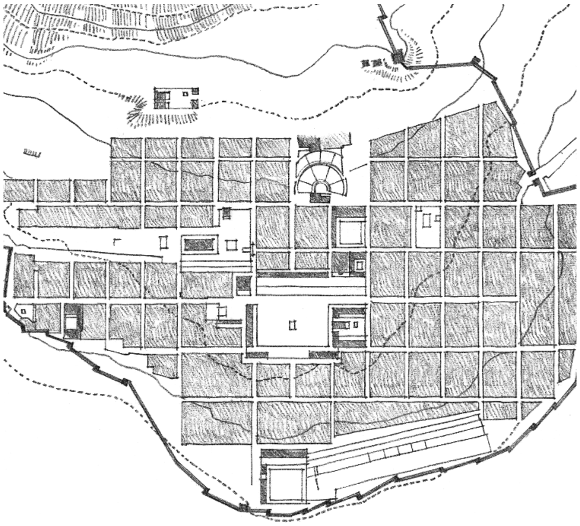


Portion of a map showing the Historic & Landmark Districts of Boston

Historic Preservation

Cities with historic districts often enact regulations to ensure that new buildings do not degrade the historic character of a place. These regulations usually incorporate more strict form and appearance guidelines and additional review procedures in order to get approval for a project to be built.

Architecture in the City



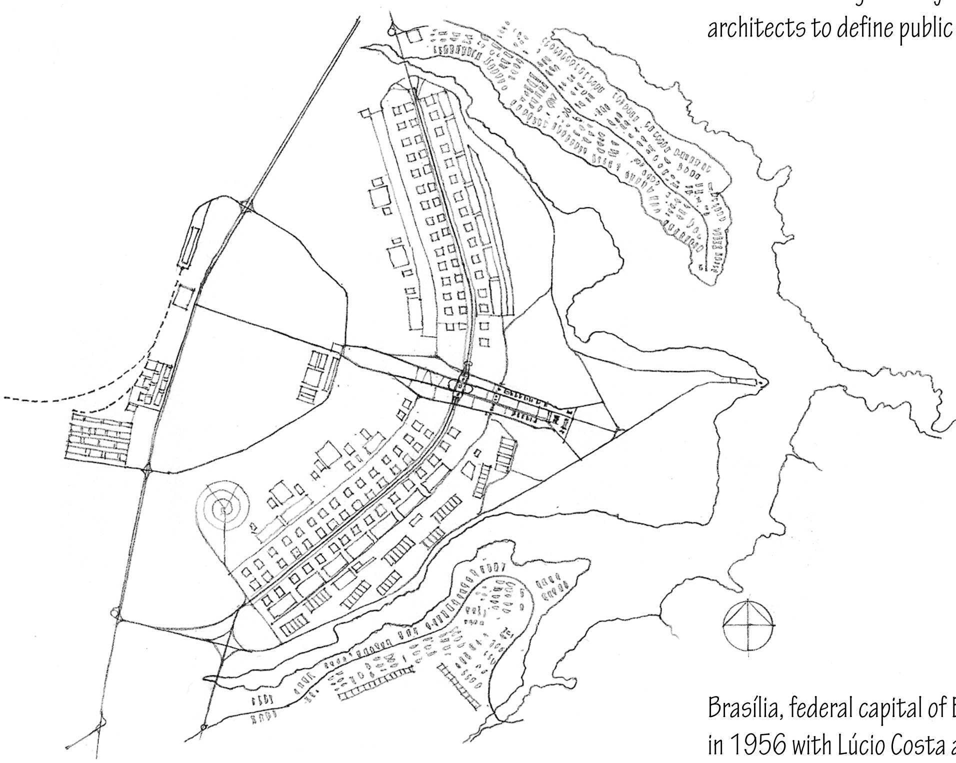
Priene, ancient Greek city of Ionia, founded fourth century BCE

Throughout history the architect has played a primary role in defining strategies for urban development. Architecture is a constructed environment much the way a city is. The relationships between spaces and functions in a building correspond directly to the same relationships in a city. Similarly, a city must provide spaces to house different functions much the same way as a building. This overlap has positioned the architect to take on a unique role of defining urban development strategies and to design the buildings that are intended to implement those strategies.

In contemporary practice urban planning has emerged as the discipline responsible for the shaping of towns and cities. It is the role of the urban planner to layout transportation systems, infrastructure, and land use strategies. The planner has a significant role in developing public policy that controls the development of cities. Because of the emergence of urban planning the role of the architect in these processes has been reduced when compared to historic models.

Urban Planning

Urban planners lay out large-scale plans of streets as well as develop land-use strategies. They also work with architects and landscape architects to define public space and the arrangement of buildings.



Brasília, federal capital of Brazil, planned and developed in 1956 with Lúcio Costa as the principal urban planner and Oscar Niemeyer as the principal architect.

Urban Design

An area where the architect still has a primary role is in urban design. Urban design differs only slightly from planning, but includes collaboration from a larger set of contributing disciplines and schools of thought. Disciplines that contribute to urban design projects include:

Architecture

Architects design buildings and works with planners and engineers to layout large-scale development strategies.

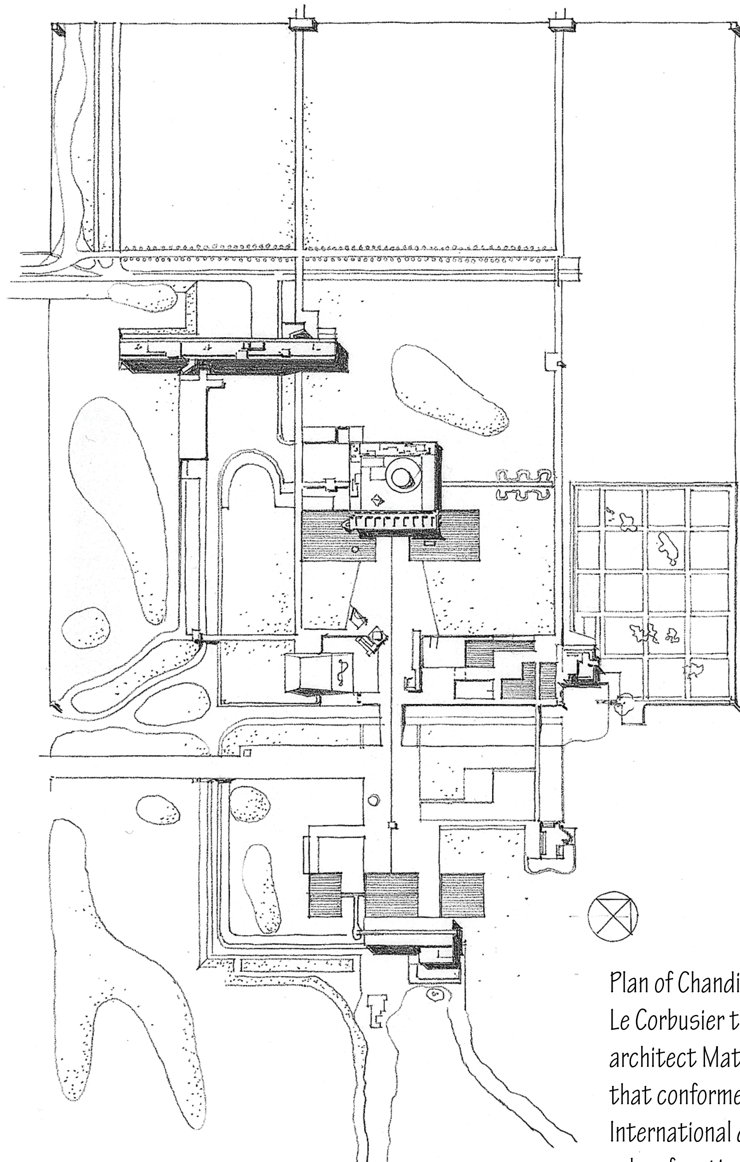
Landscape Architecture

Landscape architects design open public spaces and streetscapes. They also work with architects to define the placement of buildings and with civil engineers to define public infrastructure.

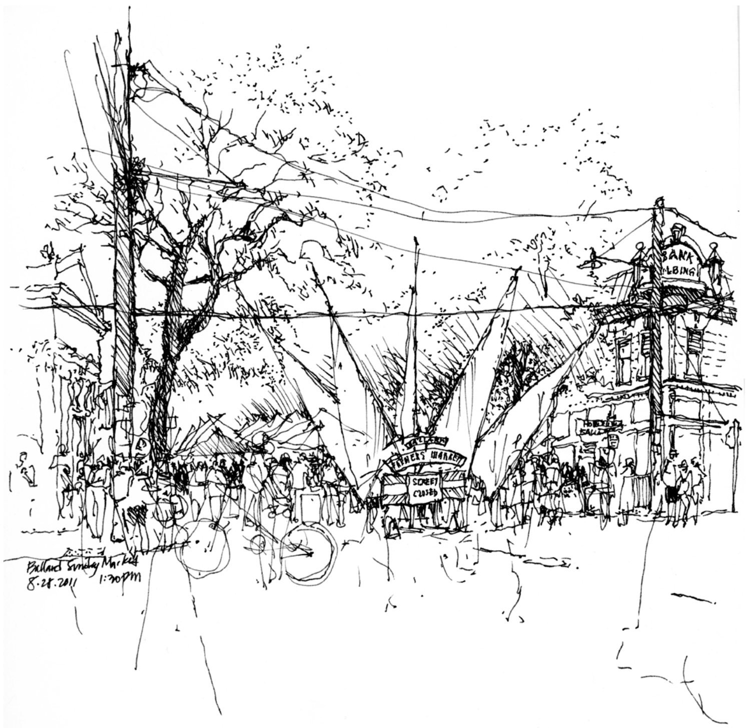
Civil Engineering

Civil engineers plan city infrastructure. They work with urban planners to lay out large-scale land-use strategies and with landscape architects to control placement of infrastructure and design elements to control water runoff and retention.

As opposed to large-scale urban strategies of planning, urban design concerns itself with a broad range of projects, at a variety of scales that influence the built environment. Urban design ideas can often be found in small-scale projects undertaken by any of the disciplines mentioned previously or can be featured large-scale collaborations in the design of a master plan.



Plan of Chandigarh, India, 1951–1962.
Le Corbusier took over from urban planner Albert Mayer and architect Matthew Nowicki and produced a plan for Chandigarh that conformed to the city planning principles of Congrès International d'Architecture Moderne (CIAM)—division of urban functions, anthropomorphic plan form, and hierarchy of road and pedestrian networks. The city features architectural works by Le Corbusier, Jane Drew, and Maxwell Fry.



Designing on a Small Scale

Even individual buildings have the potential to contribute to the development of the urban environment. Essentially there are three positions to take when designing a project for the city. Each one forecasts the future of that place and develops schemes to suit it. It is through these positions that architecture can influence the direction of urban development.

Response to the Existing

One position an architect can take is to design a building that suits immediate needs and fits into the fabric of a city, as it currently exists. This position is one that seeks to preserve existing conditions of the urban environment. It also assumes that needs will remain constant and, therefore, the architectural proposal will continue to function properly into the near future. This is the best course to take when designing a building for a successful, thriving community.

The following are some advantages of this strategy:

Maintain sense of place

- The traditions and practices of the residents of this area should be unimpeded by the new architecture because it is the result of study of the surrounding area and the way people use it.

Preserve successful characteristics of the area

- This strategy seeks to disrupt the functions of the neighborhood or district as little as possible. Therefore, successful characteristics should be easily preserved as the city develops.

Possible disadvantages to using this strategy:

Developmental stagnation

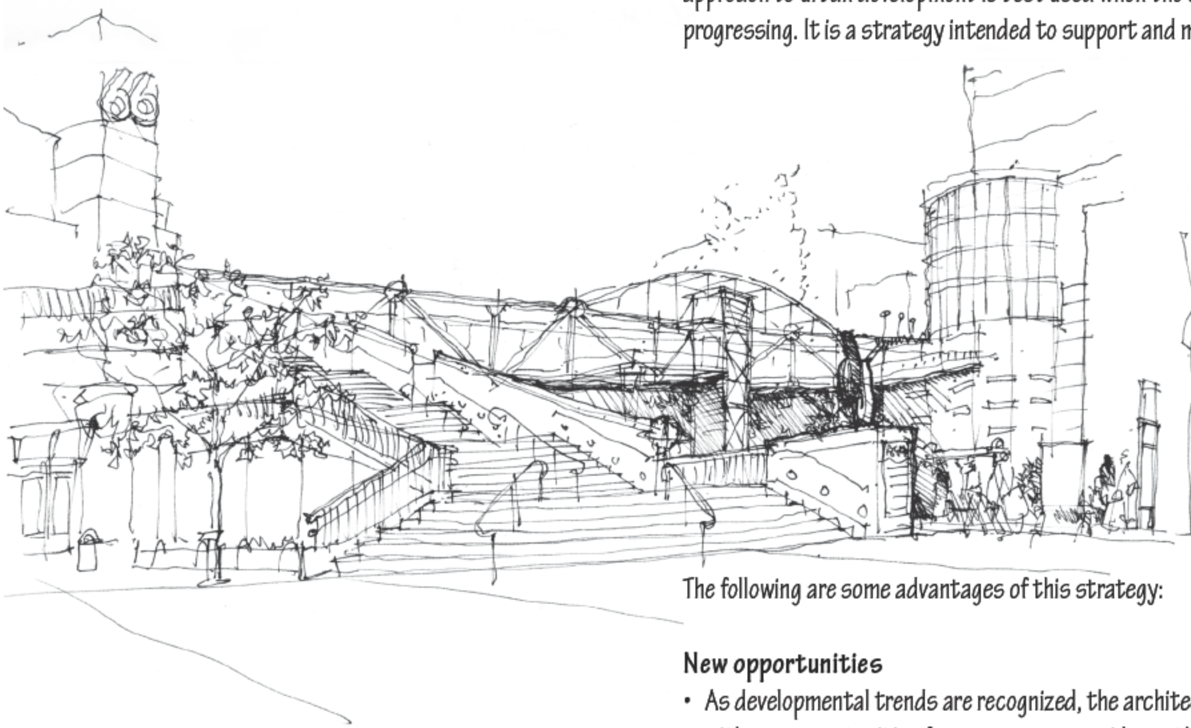
- When one neighborhood maintains successful characteristics without adding new amenities, nearby advancing neighborhoods will begin to surpass it in terms of its economy and social ties with its residents.

Doesn't recognize changes that are actually occurring

- If the demographics of a place are shifting, yet the design strategies for that place remain constant, eventually new buildings will no longer fully meet the needs of the population they are intended to serve. This is often caused by misunderstanding the physical and social context of a site.

Response to a Trend

In a situation where the evolution of an urban environment can be observed, an architect might choose to respond to that developmental trend. Instead of designing a building that is perfectly suited to present conditions, the goal here is to predict the conditions that will arise as a result of ongoing changes and respond to those. This position is one in which urban development can be supported by architecture. The architecture that comes about as a result of this mind set is one that looks to emergent ideas and recent projects for guidance in transforming a city. A forward-thinking approach to urban development is best used when the city is growing and progressing. It is a strategy intended to support and maintain that growth.



The following are some advantages of this strategy:

New opportunities

- As developmental trends are recognized, the architect can infuse the area with new opportunities for commerce or residence that support progress.

Population growth

- An area becomes more likely to attract new population as greater access to a wider variety of urban amenities is achieved.

Possible disadvantages to using this strategy are:

Gentrification

- If advancement occurs at the expense of the population that lives in a place, it tends to lead toward gentrification as opposed to actual advancement of a group of people. If a current population does not benefit from the development, that group is usually replaced by one that does. This causes the original population to be displaced to other districts of the city.

Misunderstanding

- If a trend is not accurately identified the architecture that is designed for the place may be inappropriate and not fully meet the needs of the population.

Altering Course

In the event that a city is changing, and not for the better, the architect might choose to develop a project that seeks to halt or change that trend. Instead of designing a building that meets the immediate needs of a place, or that assumes that urban decline is inevitable, the goal here is to redirect the development of the built environment. The architecture that results from this mind set is one that seeks to add new amenities, infrastructure, or other resources to an area in order to attract ongoing investment and foster continued advancement.

This is often the position taken for designs in cities suffering from population decline or the loss of a major industry. Sometimes called urban renewal, places with growing poverty or crime rates can sometimes benefit from an influx of new amenities.

The following are some advantages of this strategy:

Commercial opportunities
- Additional commercial opportunities provide more avenues for employment as well as access to a wider range of goods and services that can empower a population. For this to be successful, the architect must be able to identify missing urban attributes and design a building that can accommodate them.

New investment
- The strategic placement of new building types in an area can also attract new investment and future development by installing a sense of stability.

Population increase
- Buildings that change an environment can also lead to reversing trends of population loss by shifting the demographic composition of a place. By adding amenities to appeal to a more diverse group of people, a district might attract new populations.

Shift in perception
- Changing the way a place is perceived creates ways to attract new businesses, residents, and visitors to drive the economy of a place.

Possible disadvantages to using this strategy:

Risk of gentrification
- If the populace that remains in this place will not benefit from the changes being made, it will be forced out due to an increased cost of living. This process of gentrification is unsustainable in that it does little to solve problems faced by a population; instead, it moves them to a different part of the city.

Underutilized design
- If the planned change in development doesn't work, the resulting building will not suit the current needs of the place. A new building that is unused or underutilized will only reflect an expenditure of resources without significant return, which will serve only to exacerbate the problems it was intended to alleviate.

Designing on a Large Scale

A key feature of urban design is the master plan. The master plan is the design of an entire neighborhood, city district, or even an entire city. The master plan contains strategies for the placement of buildings, open spaces, streets, and infrastructure.

This is a strategy for urban development that relies on interdisciplinary collaboration to achieve rapid expansion or advancement of a city. In these scenarios different individuals collaborating toward a single objective make design decisions at several scales.

- A city or neighborhood plan will be developed that covers the design of large-scale infrastructure, transportation networks, land use, and distribution of public and private spaces. This plan serves to outline strategies for development.
- Public spaces and streetscapes will be designed with a greater degree of detail in a way that fits into the original plan.
- Various aspects of the plan will be distributed to different members of the design team for further development.
- Team members design their designated project with a greater degree of detail in a way that fits into the original plan.
- Master planners oversee the different small projects to ensure that they contribute to the strategies and ideas of the overall project.

These efforts work well in areas that are experiencing rapid population growth. They imbue the urban design process with efficiency necessary to keep up with economic advancement and population increases. However, these strategies are also sometimes used as a way of initializing growth by injecting a declining or stagnating city with large quantities of capital and civic amenities that serve to attract new residents and businesses to a location.

Efficiency comes with trade-offs. With rapid, large-scale, development created by a relative few designers these projects are rarely able to consider subtle socio-cultural aspects of the city. Because they are not developed over time in response to specific needs of an existing population, they often lack a sense of place, and community ties must be created anew.

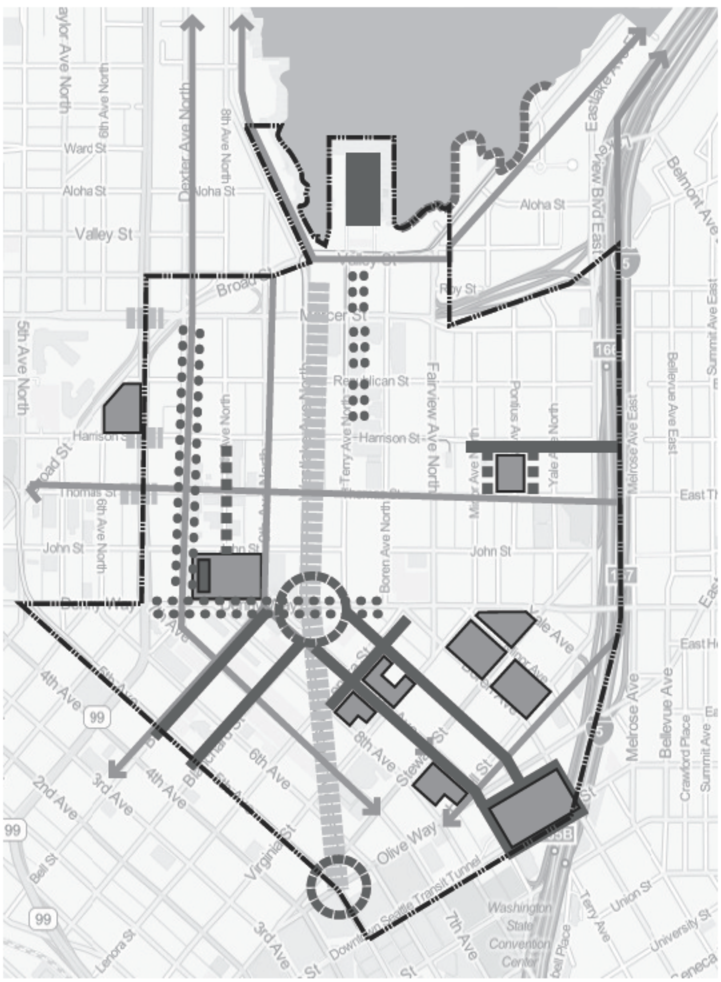


Diagram based on the Seattle Parks and Recreation plan of 2004 that sets goals for the amount and type of open space in South Lake Union.

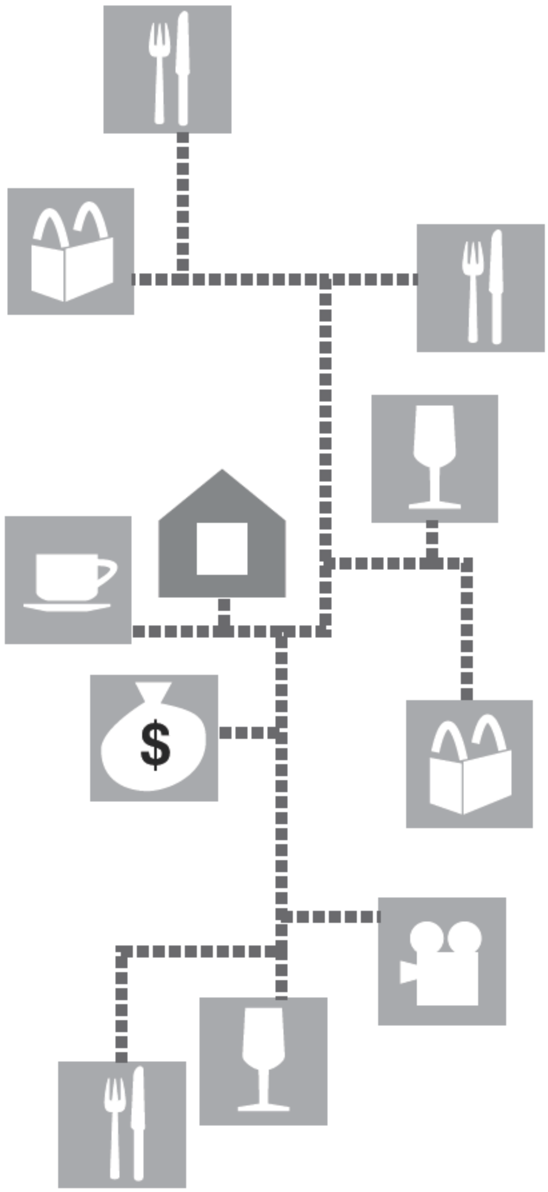
Community and Sense of Place

One of the ways that architecture can have an impact on a city is through establishing or maintaining a sense of place. A sense of place refers to the particular set of local traditions and practices that defines a community of people.

To do this, architecture can create space at both the scale of the building and the city that provides the opportunity for a community to prosper through social interaction. Architecture also has the potential to foster community in places where one has not yet been established.

To do this, the architect must consider several issues as a part of the design process.

- Access to urban amenities
- Relation between private and public; domestic and civic
- Communal open space



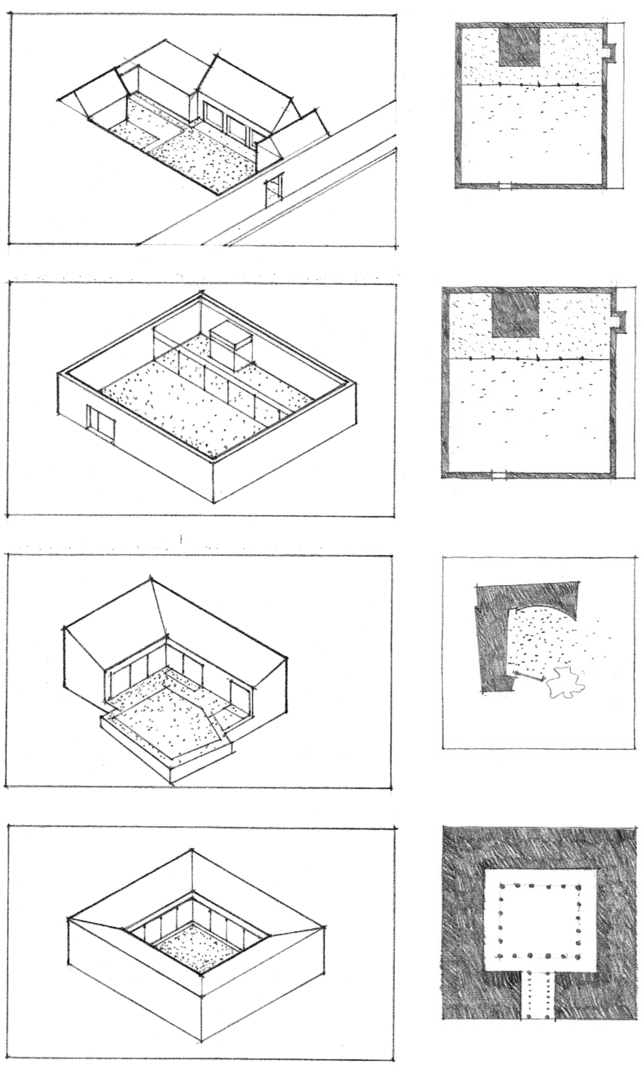
Access to Urban Amenities

An urban amenity is any resource to which a resident of a city might have access. These resources might be the simple necessities for a dwelling, or opportunities for social events and cultural exploration.

A rule of thumb for urban design is that any amenity required to support the typical lifestyle of an area should be within a 15-minute walk of any location in the area. This simple rule limits the need for transportation. Pedestrians experience more of the city around them. They encounter more people and potentially form ties with those people. Even though they venture out for one specific good or service, they may encounter another along the way.

The pedestrian forms social bonds with other members of the community. On the other hand, those that rely on a car for transportation often avoid the encounters that foster social connections. It is more likely for the pedestrian to become invested in the neighborhood and seek to preserve the qualities and conditions that make it unique.

Architecture plays a significant role in defining access to urban amenities. When an architect is designing a building, there is a phase where the program of the building is being refined. During this phase the architect works with a client to decide what functions the building must fulfill. If there is any program not available within a 15-minute walk, then it is likely that the design will be more successful if it incorporates that program. This requires research and observation of the context of a project.



Relationships between Public and Private

The interface between public and private space has many implications for establishing a sense of community. Whatever the relationship between domestic and civic, it is a condition that reflects the culture and social practices of the people that live in a place.

Domestic Adjacent to Civic

- Some places might have direct access from the private, domestic spaces to the public, civic spaces. In such instances, houses might open to parks, public gardens, or even to richly programmed streetscapes. This provides a resident with immediate access to urban amenities as well as infrastructure, and it creates opportunities to develop community ties with neighbors. In this scenario, social interaction takes place immediately adjacent to one's own residence.

Domestic Separate from Civic

- Other places might have a less direct connection, where the interface is actually a buffering mechanism such as a porch or front yard. These scenarios create more of a separation between the private domestic environment and the social interactions of the civic environment. These scenarios might also foster smaller, more tightly knit community structures.

Composing Architecture

- The composition of architecture can define, facilitate, or limit the social interaction upon which community is based. At the macro scale, the position of a building on its site develops certain relationships between the spaces within the building and the civic space around it. These relationships are under the control of the architect as s/he arranges programs on the site and orients the building relative to characteristics of the surrounding civic environment. At the micro scale, the position of individual rooms relative to exterior characteristics can define the relationship between individual building functions and the building's context. The kind of access an occupant has is also important. The architect must consider where one enters an interior space from the outside, where one has access (physical, visual, or auditory) to the outside. The facade of a building facilitates many of these smaller-scale relationships between private and public. To some extent, the facade determines social roles that individuals play within a community. It acts as a filter that defines where public space ends and private space begins. It also determines the level of awareness the public has to the functions of the interior. All of these characteristics help to position a building within a community structure.

Communal Open Space

Architecture plays a role in providing opportunity for community to exist by creating a semi-public or semi-private realm wherein community can thrive. These strategies speak to a priority for integrating the architectural unit into the urban landscape. They result in an architectural proposal that is specifically suited its context, both social and physical, which is vital in creating and maintaining a sense of community, and a sense of place.

This is important enough that sometimes an architect will sacrifice some space for a building to provide these open accessible areas. Some buildings provide opportunities of for the public realm to enter or overlap the private.

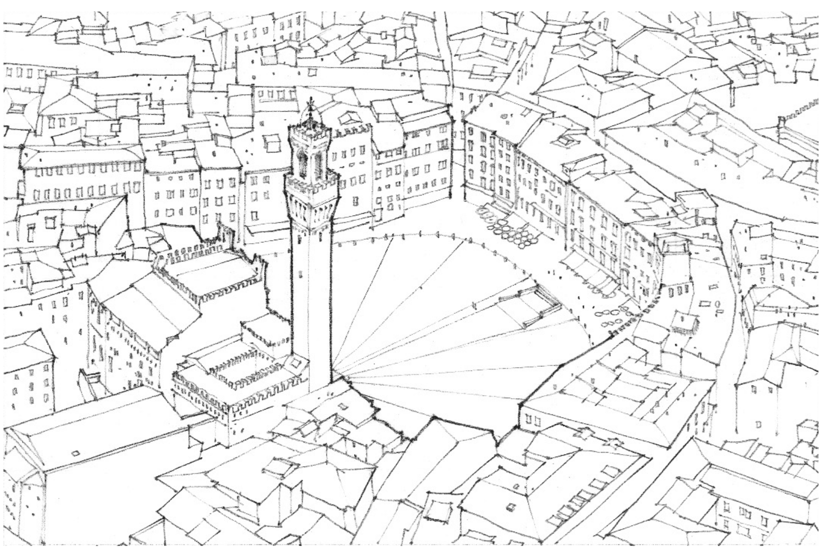
Square in Giron, Colombia

Park

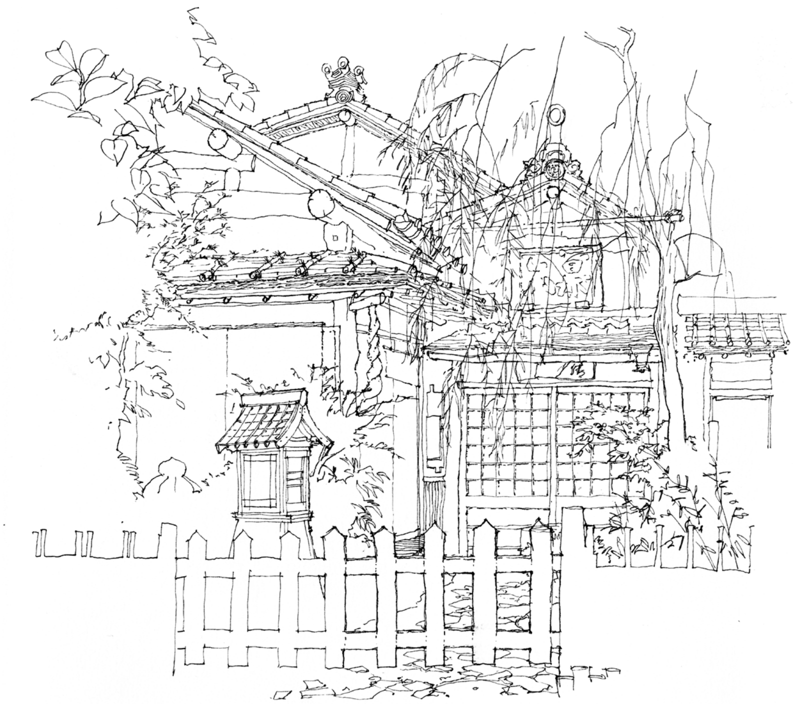
- Architecture adjacent to a large park has the opportunity to take advantage of activities of the park to drive the layout of spaces within the building. Windows might be placed in an apartment to provide a view of events in the park. Businesses that cater to the specific activities in the park might be attracted to buildings along its periphery.

Promenade

- A promenade is an open public space that serves to link other facets of the public environment. It might take the form of a plaza surrounded by shops and restaurants for instance. The distinction between inside and outside becomes blurred as portions of the shops extend out into the promenade to attract customers.



Piazza del Campo, Siena, Italy



Residence in Asakusa district of Tokyo

Garden or Yard

- Architecture off of a smaller public garden or yard incorporates the notion of open space into the design of the building. The private spaces of the building are separated from the public spaces of the city by a semi-public garden or yard. These conditions can occur as a private front lawn for a house, or a public garden that separates a residential building from the street.

Porch

- Architecture with a porch leading to the street provides separation between the public and the private similar to that established by the yard. In this instance, however, the porch is an intervening structure that carries public activity to the private spaces inside. The porch becomes a semi-private zone where public interaction can be invited into the architecture without permitting it access to the private spaces inside.

Sidewalk cafe in Orlando, Florida

Sidewalk

- Architecture that extends into the sidewalk has intentionally little separation between public and private. These buildings offer immediate access to the public activities of a city. Here, the spaces of a residence might have more public functions clustered around the entry and hold the private areas above or behind them. Businesses may have direct access to the sidewalk to attract customers or even have portions of their own program project out into the public space. A cafe might have seating directly on the sidewalk to promote a social interaction that extends from the public exterior into the functions of the interior.

Glossary

abstract Of or pertaining to shapes and forms having an intellectual and affective content dependent solely on their intrinsic lines, colors, and relationship to one another.

abutment The part of a structure that directly receives thrust or pressure, such as a masonry mass receiving and supporting the thrust of an arch or vault; a heavy wall supporting the end of a bridge or span and sustaining the pressure of the abutting earth; or the anchorage for the cables of a suspension bridge.

acoustics The branch of physics that deals with the production, control, transmission, reception, and effects of sound.

acropolis The fortified high area or citadel of an ancient Greek city, esp. the citadel of Athens and site of the Parthenon.

adobe Sun-dried brick made of clay and straw, commonly used in countries with little rainfall.

aedicule A canopied opening or niche flanked by two columns, piers, or pilasters supporting a gable, lintel, or entablature.

Americans with Disabilities Act An act of Congress that became law in 1992, establishing design standards and requirements for all buildings except single-family residences to ensure their accessibility by the physically disabled.

analysis Separating of a whole into its constituent parts or elements, esp. as a method of studying the nature of the whole and determining its essential features and their relations.

analytique An elevation drawing of a facade, surrounded by a decorative arrangement of drawings of important details and sometimes a plan or section of the facade.

anthropomorphism A conception or representation resembling the human form or having human attributes.

arcade A series of arches supported on piers or columns.

arch A curved structure for spanning an opening, designed to support a vertical load primarily by axial compression.

architectonics The unifying structure or concept of an artistic work.

architecture 1. The art and science of designing and constructing buildings. 2. The product or result of architectural work; buildings, collectively. 3. A style or method of building characteristic of a people, place, or time. 4. The profession of designing buildings and other habitable environments. 5. The conscious act of forming things, resulting in a unifying or coherent structure.

articulation A method or manner of jointing that makes the united parts clear, distinct, and precise in relation to each other.

avant-garde The advance group in any field, esp. in the visual, literary, or musical arts, whose works are characterized chiefly by unorthodox and experimental methods.

axis A straight line to which elements in a composition are referred for measurement or symmetry.

axonometric A paraline drawing of an axonometric projection, having all lines parallel to the three principal axes drawn to scale but diagonal and curved lines distorted.

axonometric projection The orthographic projection of a three-dimensional object inclined to the picture plane in such a way that its three principal axes are foreshortened.

bay A major spatial division, usually one of a series, marked or partitioned off by the principal vertical supports of a structure.

beam A rigid structural member designed to carry and transfer transverse loads across space to supporting elements.

bearing A point, surface, or mass that supports weight, esp. the area of contact between a bearing member, such as a beam or truss, and a column, wall, or other underlying support.

bedrock The unbroken, solid rock that underlies all unconsolidated material on the earth's surface, such as soil, clay, sand, or rock fragments.

bond Any of various arrangements of masonry units having a regular, recognizable, usually overlapping pattern to increase the strength and enhance the appearance of the construction.

brick A masonry unit of clay, formed into a rectangular prism while plastic and hardened by drying in the sun or firing in a kiln.

building code A code regulating the design, construction, alteration, and repair of buildings, adopted and enforced by a local government agency to protect the public safety, health, and welfare.

cable support A cable anchorage that allows rotation but resists translation only in the direction of the cable.

cantilever A beam or other rigid structural member extending beyond a fulcrum and supported by a balancing member or a downward force behind the fulcrum.

cement A calcined mixture of clay and limestone, finely pulverized and used as an ingredient in concrete and mortar. The term is frequently used incorrectly for concrete.

charrette An intense effort to complete a design project within a specified time.

city planning The activity or profession of determining the future physical arrangement and condition of a community, involving an appraisal of the current conditions, a forecast of future requirements, a plan for the fulfillment of these requirements, and proposals for legal, financial, and constructional programs to implement the plan.

civilization An advanced state of human society marked by a relatively high level of cultural, technical, and political development.

clerestory A portion of an interior rising above adjacent rooftops and having windows admitting daylight to the interior.

cloister A covered walk having an arcade or colonnade on one side opening onto a courtyard.

coffer One of a number of recessed, usually square or octagonal panels in a ceiling, soffit, or vault.

column A rigid, relatively slender structural member designed primarily to support compressive loads applied at the member ends.

composition The arranging of parts or elements into proper proportion or relation so as to form a unified whole.

compression The act of shortening or state of being pushed together, resulting in a reduction in size or volume of an elastic body.

computer-aided design The use of computer technology in the design of real or virtual objects and environments. The term includes a variety of software and hardware technologies, from the vector-based drawing and drafting of lines and figures in two-dimensional space (2D CAD) to the modeling and animation of surfaces and solids in three-dimensional (3D CAD) space. Abbr.: CAD

concentrated load A load acting on a very small area or particular point of a supporting structural element.

concrete An artificial, stonelike building material made by mixing cement and various mineral aggregates with sufficient water to cause the cement to set and bind the entire mass.

construction The art, science, or business of building.

construction type A classification of a building's construction according to the fire resistance of its major components— structural frame, exterior bearing and nonbearing walls, interior bearing walls, floors and ceilings, roofs, and enclosures of fire exits and vertical shafts—serving to limit the area and height of a building according to intended occupancy.

course A continuous, usually horizontal range of bricks, tiles, or shingles, as in a wall or roof.

cricket A small roof for diverting rainwater around a projection, such as a chimney, on a sloping roof.

culture The integrated pattern of human knowledge, beliefs, and behaviors built up by a group of human beings and transmitted from one generation to the next.

datum An assumed, given, or otherwise determined fact or proposition from which conclusions may be drawn or decisions made.

dead load The static load acting vertically downward on a structure, comprising the self-weight of the structure and the weight of building elements, fixtures, and equipment permanently attached to it.

deep foundation A foundation system that extends down through unsuitable soil to transfer building loads to a more appropriate bearing stratum well below the superstructure.

design To conceive, contrive, or devise the form and structure of a building or other construction.

design concept A concept for the form, structure, and features of a building or other construction, represented graphically by diagrams, plans, or other drawings.

design principle A fundamental and comprehensive concept of visual perception for structuring an aesthetic composition.

design-build Of or pertaining to an arrangement under which a person or organization contracts directly with an owner to design and construct a building or project.

diagram A drawing, not necessarily representational, that outlines, explains, or clarifies the arrangement and relations of the parts of a whole.

distributed load A load extending over the length or area of the supporting structural element.

dome A vaulted structure having a circular plan and usually the form of a portion of a sphere, so constructed as to exert an equal thrust in all directions.

door A hinged, sliding, or folding barrier of wood, metal, or glass for opening and closing an entrance to a building, room, or cabinet.

dormer A projecting structure built out from a sloping roof, usually housing a vertical window or ventilating louver.

drawing The art, process, or technique of representing an object, scene, or idea by means of lines on a surface.

dynamic load A load applied suddenly to a structure, often with rapid changes in magnitude and location. Under a dynamic load, a structure develops inertial forces in relation to its mass and its maximum deformation does not necessarily correspond to the maximum magnitude of the applied force.

elevation An orthographic projection of an object or structure on a vertical picture plane parallel to one of its sides, usually drawn to scale.

embodied energy All of the energy expended during the life cycle of a material or product: the sum of the energy used in growing, extracting, manufacturing, assembling, transporting, installing, disassembling, deconstructing, disposing, and decomposition of a resource.

engineering The art and science of applying scientific principles to practical ends in the design and construction of structures, machines, and systems.

fenestration The design, proportioning, and disposition of windows and other exterior openings of a building.

flight A continuous series of steps between one floor or landing of a building and the next.

form The shape and structure of something as distinguished from its substance or material.

framework A skeletal structure of parts fitted and joined together in order to support, define, or enclose.

framing The act, process, or manner of fitting and joining together relatively slender members to give shape and support to a structure.

frieze A decorative band, as one along the top of an interior wall, immediately below the cornice, or a sculptured one in a stringcourse on an outside wall.

front To face in a specific direction or look out upon.

function The natural or proper action for which something is designed, used, or exists.

geometric Of or pertaining to shapes and forms that resemble or employ the simple rectilinear or curvilinear elements of geometry.

golden section A proportion between the two dimensions of a plane figure or the two divisions of a line, in which the ratio of the smaller to the larger is the same as the ratio of the larger to the whole: a ratio of approximately 0.618 to 1.000.

girder A large principal beam designed to support concentrated loads at isolated points along its length.

green Descriptive of a material, product, or process not considered to be harmful to the environment.

green building Building to provide healthy environments in a resource-efficient manner, using ecologically based principles. While the terms "green building" and "sustainable design" are often used interchangeably, sustainability calls for a whole-systems approach to development that encompasses the notion of green building but also addresses broader social, ethical, and economic issues, as well as the community context of buildings.

green facade A green wall having the climbing vegetation rooted in the ground and growing up either directly on the wall or on specially designed supporting structures.

green roof A roof of a building that is partially or completely covered with vegetation, a growing medium, and drainage system, installed over a waterproof membrane to lower building temperatures, reduce the heat island effect, lessen stormwater runoff, and absorb carbon dioxide from the air.

green wall A wall that is partially or completely covered with vegetation and, in some cases, soil or an inorganic growing medium.

haptic Relating to or based on the sense of touch.

harmony The orderly, pleasing, or congruent arrangement of the elements or parts in an artistic whole.

hearth The floor of a fireplace, usually of brick, tile, or stone, often extending a short distance into a room.

Hellenic Of or pertaining to ancient Greek history, culture, and art, esp. before the time of Alexander the Great.

Hellenistic Of or pertaining to Greek history, culture, and art from the time of Alexander the Great's death in 323 BCE through the 1st century BCE, during which Greek dynasties were established in Egypt, Syria, and Persia, and Greek culture was modified by foreign elements.

history A systematic, often chronological narrative of significant events as relating to a particular people, country, or period, often including an explanation of their causes.

human scale The size or proportion of a building element or space, or an article of furniture, relative to the structural or functional dimensions of the human body.

interior design The art, business, or profession of planning the design and supervising the execution of architectural interiors, including their color schemes, furnishings, fittings, finishes, and sometimes architectural features.

International Building Code A comprehensive, coordinated national model building code developed, published, and maintained by the International Code Council (ICC), composed of representatives of the three prior model-code agencies and headquartered in Washington, D.C. Abbr.: IBC

interstice A small or narrow intervening space between things or parts.

isometric A paraline drawing of an isometric projection, having all lines parallel to the principal axes drawn to true length at the same scale.

kinesthesia The sensory experience of bodily position, presence, or movement derived chiefly from stimulation of nerve endings in muscles, tendons, and joints.

landscape architecture The art, business, or profession of designing, arranging, or modifying the features of a landscape for aesthetic or practical reasons.

life-cycle assessment Evaluating the full range of environmental and social consequences assignable to a product, process, and service from-cradle-to-grave, such as the impacts created throughout the life of a building product from the gathering of raw materials through materials processing, manufacturing, distribution, use, maintenance, and disposal or recycling.

live load Any moving or movable load on a structure resulting from occupancy, collected snow and water, or moving equipment. A live load typically acts vertically downward, but may act horizontally as well to reflect the dynamic nature of a moving load.

living wall A self-sufficient vertical garden attached to the exterior or interior wall of a building, consisting of a structural frame, layers of geotextile material, soil or other growing medium, an automatic irrigation system, and plant materials.

load Any of the forces to which a structure is subjected.

louver An opening fitted with slanting, fixed or movable slats to admit air but exclude rain and snow or to provide privacy.

mass The physical volume or bulk of a solid body.

massing A unified composition of two-dimensional shapes or three-dimensional volumes, esp. one that has or gives the impression of weight, density, and bulk.

material Matter having unique qualities by which it may be categorized.

merge To combine, blend, or unite gradually by stages so as to blur identity or distinctions.

Mesoamerica The area extending from central Mexico and the Yucatán Peninsula to Honduras and Nicaragua in which pre-Columbian civilizations flourished. These cultures shared temple-pyramids and a pantheon of deities including sun, wind, and rain gods, and excelled in astronomy and the measurement of time.

Middle Ages The time in European history between classical antiquity and the Renaissance, often dated from 476 CE, when Romulus Augustulus, the last Roman emperor of the Western Roman Empire, was deposed, to about 1500.

model code A building code developed by an organization of states, professional societies, and trade associations for adoption by local communities.

modernism A deliberate philosophical and practical estrangement from the past in the arts and literature occurring in the course of the 20th century and taking form in any of various innovative movements and styles.

modular design Planning and design utilizing prefabricated modules or modular coordination for ease of erection, flexible arrangement, or variety of use.

module Any in a series of standardized, frequently interchangeable components used in assembling units of differing size, complexity, or function.

monitor A raised construction straddling the ridge of a roof, having windows or louvers for lighting or ventilating a building.

mortar A plastic mixture of lime or cement, or a combination of both, with sand and water, used as a bonding agent in masonry construction.

Neolithic Of or relating to the last phase of the Stone Age, characterized by the cultivation of grain crops, domestication of animals, settlement of villages, manufacture of pottery and textiles, and use of polished stone implements; thought to have begun 9000–8000 BCE.

oblique A paraline drawing of an oblique projection, having all lines and faces parallel to the picture plane drawn to exact scale, and all receding lines perpendicular to the picture plane shown at any convenient angle other than 90°, sometimes at a reduced scale to offset the appearance of distortion.

olfactory Relating to or based on the sense of smell.

open plan A floor plan having no fully enclosed spaces or distinct rooms.

order A condition of logical, harmonious, or comprehensible arrangement in which each element of a group is properly disposed with reference to other elements and to its purpose.

organic Of or pertaining to shapes and forms having irregular contours that appear to resemble those of living plants or animals.

organization The systematic arranging of interdependent or coordinated parts into a coherent unity or functioning whole.

orientation The position of a building on a site in relation to true north, to points on the compass, to a specific place or site feature, or to local conditions of sunlight, wind, and drainage.

orthographic projection A method of projection in which a three-dimensional object is represented by projecting lines perpendicular to a picture plane.

panel A prefabricated section of a floor, wall, ceiling, or roof, handled as a single unit in the assembly and erection of a building.

parti The basic scheme or concept for an architectural design, represented by a diagram.

pattern An artistic or decorative design, esp. one having a characteristic arrangement and considered as a unit, of which an idea can be given by a fragment.

pediment The low-pitched gable enclosed by the building's horizontal and raking cornices of a Greek or Roman temple. Also, a similar or derivative element used to surmount a major division of a facade or crown an opening.

perspective The faculty of seeing things in their true relations or of evaluating their relative significance.

perspective drawing A drawing that represents three-dimensional objects and spatial relationships on a two-dimensional surface as they might appear to the eye.

pillar An upright, relatively slender shaft or structure, usually of brick or stone, used as a building support or standing alone as a monument.

piloti Any of a series of columns supporting a building above an open ground level.

pin joint A structural connection that allows rotation but resists translation in any direction.

plan An orthographic projection of the top or section of an object or structure on a horizontal plane, usually drawn to scale.

plaza A public square or open space in a city or town.

plenum The space between a suspended ceiling and the floor structure above, esp. one that serves as a receiving chamber for conditioned air to be distributed to inhabited spaces or for return air to be conveyed back to a central plant for processing.

plumbing The system of pipes, valves, fixtures, and other apparatus of a water supply or sewage system.

post A stiff vertical support, esp. a wooden column in timber framing.

post-modernism A movement in architecture and the decorative arts that developed in the 1970s in reaction to the principles and practices of modernism, encouraging the use of elements from historical vernacular styles and often playful illusion, decoration, and complexity.

prefabricate To fabricate or manufacture beforehand, esp. in standardized units or components for quick assembly and erection.

presentation drawing Any of a set of design drawings made to articulate and communicate a design concept or proposal, as for exhibition, review, or publication.

promenade An area used for a stroll or walk, esp. in a public place, as for pleasure or display.

proportion The comparative, proper, or harmonious relation of one part to another or to the whole with respect to magnitude, quantity, or degree.

rammed earth A stiff mixture of clay, sand or other aggregate, and water, compressed and dried within forms as a wall construction.

ramp A sloping floor, walk, or roadway connecting two levels. Building codes require the maximum slope of accessible ramps to be 1:12 with a maximum run of 30 in. (760) between landings.

regulating line A line drawn to measure or express alignment, scale, or proportion.

Renaissance The activity, spirit, or time of the humanistic revival of classical art, literature, and learning originating in Italy in the 14th century and extending to the 17th century, marking the transition from the medieval to the modern world.

repetition The act or process of repeating formal elements or motifs in a design.

rhythm Movement characterized by a patterned repetition or alternation of formal elements or motifs in the same or a modified form.

rigid joint A structural connection that maintains the angular relationship between the joined elements, restrains rotation and translation in any direction, and provides both force and moment resistance.

roller support A structural support that allows rotation but resists translation in a direction perpendicular into or away from its face.

roof The external upper covering of a building, including the frame for supporting the roofing.

scale A certain proportionate size, extent, or degree, usually judged in relation to some standard or point of reference.

scupper An opening in the side of a building, as in a parapet, for draining off rainwater.

section An orthographic projection of an object or structure as it would appear if cut through by an intersecting plane to show its internal configuration, usually drawn to scale.

serendipity An aptitude for making desirable and unexpected discoveries by accident.

shallow foundation A foundation system placed directly below the lowest part of a substructure and transferring building loads directly to the supporting soil by vertical pressure.

shape The outline or surface configuration of a particular form or figure. While form usually refers to the principle that gives unity to a whole and often includes a sense of mass or volume, shape suggests an outline with some emphasis on the enclosed area or mass.

shear The lateral deformation produced in a body by an external force that causes one part of the body to slide relative to an adjacent part in a direction parallel to their plane of contact.

shell 1. The exterior framework or walls and roof of a building. 2. A thin, curved plate structure, shaped to transmit applied forces by compressive, tensile, and shear stresses acting in the plane of the surface.

site The geographic location of a construction project, usually defined by legal boundaries.

society An enduring and cooperating large-scale community of people having common traditions, institutions, and identity, whose members have developed collective interests and beliefs through interaction with one another.

solid A geometric figure having the three dimensions of length, breadth, and thickness.

space The three-dimensional field in which objects and events occur and have relative position and direction, esp. a portion of that field set apart in a given instance or for a particular purpose.

space frame A three-dimensional structural frame based on the rigidity of the triangle and composed of linear elements subject only to axial tension or compression. The simplest spatial unit of a space frame is a tetrahedron having 4 joints and 6 structural members.

space planning The aspect of architecture and interior design that deals with the planning, layout, design, and furnishing of spaces within a proposed or existing building.

span The extent of space between two supports of a structure. Also, the structure so supported.

stair One of a flight or series of steps for going from one level to another, as in a building.

stairway A passageway from one level of a building to another by a flight of stairs.

static load A load applied slowly to a structure until it reaches its peak value without fluctuating rapidly in magnitude or position. Under a static load, a structure responds slowly and its deformation reaches a peak when the static force is maximum.

stilt One of several piles or posts for supporting a structure above the surface of land or water.

Stone Age The earliest known period of human culture, preceding the Bronze Age and the Iron Age and characterized by the use of stone implements and weapons.

story A complete horizontal division of a building, having a continuous or nearly continuous floor and comprising the space between two adjacent levels. Also, the set of rooms on the same floor or level of a building.

structure The organization of elements or parts in a complex system as dominated by the general character of the whole.

style A particular or distinctive form of artistic expression characteristic of a person, people, or period.

sustainable design A design approach that emphasizes efficiency and moderation in the use of materials, energy, and spatial resources, requiring paying attention to the predictable and comprehensive outcomes of decisions, actions and events throughout the life cycle of a building, from conception to the siting, design, construction, use, and maintenance of new buildings as well as the renovation process for existing buildings and the reshaping of communities and cities.

symbol Something that stands for or represents something else by association, resemblance, or convention, deriving its meaning chiefly from the structure in which it appears.

synthesis Combining of separate, often diverse parts or elements so as to form a single or coherent whole.

system A group of interacting, interrelated, or interdependent things or parts forming a complex or unified whole, esp. to serve a common purpose.

systems building A construction process using a high degree of prefabrication in the manufacture of standardized units or components to speed assembly and erection of a building.

tactile texture The physical, dimensional structure of a surface, apart from its color or form.

tectonics The science or art of shaping, ornamenting, or assembling materials in building construction.

tension The act of stretching or state of being pulled apart, resulting in the elongation of an elastic body.

texture The visual and esp. tactile quality of a surface, apart from its color or form.

theory Abstract thought or speculation resulting in a system of assumptions or principles used in analyzing, explaining, or predicting phenomena, and proposed or followed as the basis of action.

threshold The sill of a doorway, covering the joint between two flooring materials or providing weather protection at an exterior doorway.

torque The moment of a force system that causes or tends to cause rotation or torsion.

transition Movement, passage, or change from one form, state, or place to another.

tread The horizontal upper surface of a step in a stair, on which the foot is placed.

uniformly distributed load A distributed load of uniform magnitude.

universal design The process of planning, designing, and creating products, buildings, and environments that are accessible to all individuals, including those with disabilities or special needs, to the greatest extent possible given current materials, technologies, and knowledge.

urban design The aspect of architecture and city planning that deals with the design of urban structures and spaces.

visual scale The size or proportion an element appears to have relative to other elements or components of known or assumed size.

visual texture The apparent texture of a surface resulting from the combination and interrelation of colors and tonal values.

void An empty space contained within or bounded by mass.

wall Any of various upright constructions presenting a continuous surface and serving to enclose, divide, or protect an area.

window An opening in the wall of a building for admitting light and air, usually fitted with a frame in which are set operable sashes containing panes of glass.

wythe A continuous vertical section of a masonry wall one unit in thickness.

zoning code An ordinance regulating the division of land into zones, so as to restrict the height, bulk, density, and use of buildings, and the provision of such ancillary facilities as parking; a principal instrument in the implementation of a master plan.

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